Hardware Set-up Guide
Physiocom GP Series Amplifiers

1 Introduction

TO_DO needs updating for new devices

This document describes how to set up the GP8 amplifier and associated sensors for use with the Mind-Body Training Tools biofeedback applications. It assumes you have already installed the software – if you haven't done that yet, please see the Installation and Set-up Guide.

A set of training videos, accessible from the launcher application, offer an alternative route to learning how to set up the amplifier and sensors. This guide goes into more depth. Don't let the technical details put you off as a full understanding isn't necessary to make use of the products.

The GP8 amplifier connects to the computer via a USB port, and supports all the biofeedback applications in the suite, meaning that it can read the following physiological signals:

- EMG (for muscle tension) – used in the EMG and breathing applications

- ECG or electro-cardiograph – used in the Heart Rate Coherence (HRC) application to calculate heart rate.

- Temperature – monitoring temperature of inhaled and exhaled air is the basis of breath measurement in both the HRC and breathing applications. Additionally it is used in the skin temperature application.

- Infra-red temperature – used in the infra-red neurofeedback applications.

In both EMG and ECG we use three sensors to give a single measurement. This may seem confusing, but it isn't necessary to understand the reasons behind this. All you really need to know is that EMG is a measure of muscle tension, and ECG gives you a heart rate.

The unit has five inputs, three at the front and two at the side, as shown in figure 1 below. The front three together are capable of recording one channel of EMG, ECG or EEG data at a sample rate of up to 1024 per second. EEG is currently not used in any Mind-Body Training Tools applications. Input 4 is used for the temperature and infra-red temperature sensors, and can read data at a sample rate of up to 512 per second. Other sensors are also available for the GP8 via inputs 4 and 5, such as a PPG (pulse wave) sensor, but they are not currently used in the Mind-Body Training Tools suite of applications. Please note, the Mind-Body Training Tools applications don't all use the maximum sample rate available – they typically use lower sample rates where the loss of precision is not relevant, in order to optimise performance.

The GP8 requires two AAA batteries. The manufacturer recommends using alkaline batteries (which give over 100 hours of operation). I have found that good quality (high power) rechargeable

Ni MH batteries work well enough. Batteries are inserted into the underside of the device – see figure 2. Battery status can be tested from the software – see section 4 below.

Figure 1 – GP8 amplifier

Figure 2 – GP8 amplifier underside with battery cover removed

2 Sensors

The following table lists all the sensors used in the Mind-Body Training Tools application suite.

Sensor	Input	Figure	Description
Set of 3 EMG/ECG cables (TP60)	White – 1 Green – 2 Black – 3	3	Used for EMG (muscle tension) and ECG (for heart rate).The white and black leads are known as the active sensors while the green is the ground.
Snap electrodes (SE23) – set of 3 with plastic mounts		4, 5	These snap into the heads of the TP60 cables above. They are used for EMG and ECG. The plastic mounts are not strictly needed.
Disposable pre-gelled electrodes		6	Alternative to SE23 electrodes above. They will give more accurate readings.
Temperature sensor (GP-1u)	4	7	Used for breath measurement in the HRC and breathing applications, and in the skin temperature application.
Infra-red temperature sensor (GP-7u)	4	8	Used for infra-red neurofeedback.

Figure 3 – Set of 3 cables (TP40) used for EMG and EKG. The plugs at the left side are inserted into the GP8 unit. The heads (right side) need to be fitted with snap electrodes (e.g. see figures 4,5 and 6) before being attached to the skin.

Figure 4 – Set of 3 snap electrodes with plastic mounts, for use with TP60 cables (figure 3)

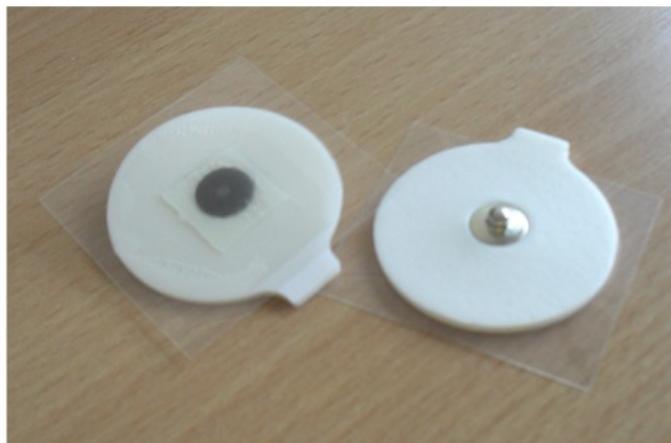Figure 5 – Snap electrode (SE23) fitted to cable, with plastic mount

Figure 6 – Disposable pre-gelled self-adhesive snap electrodes

Figure 7 – Infra-red temperature sensor

Figure 8 – Temperature sensor

3 Attaching the Sensors to the Body

This section covers how to attach the sensors to the body. There is a sub-section for each application. For both EMG and ECG, the accuracy of the measurement depends in part on the quality of the connection to the skin. Therefore we begin with a general discussion of accuracy in EMG and ECG measurement.

3.1 Accuracy in EMG and ECG Measurement

The accuracy of EMG and ECG measurement depends on several factors including hardware and software design. Practically speaking, perhaps the most significant factor is the quality of the electrical contact between the sensor and the skin. This is quantified *impedance*. You don't need to understand exactly what impedance is, only that broadly speaking the lower the impedance the more accurate your measurement. However in biofeedback, since we are usually more concerned with relative changes than with absolute measurements, we can often sacrifice some accuracy for

the sake of convenience. As long as the impedances are stable over time then we can still run effective biofeedback sessions with relatively high impedances.

For both EMG and ECG there are three sensors. Think of EMG and ECG as a kind of voltage. A voltage is always a difference between two points, so we measure two voltages. Two of the sensors are known as the actives (white and black), the third is the ground (green). One voltage is the difference between Active 1 and the ground, and the other voltage is between Active 2 and the ground.

Likewise we have two impedances.

In the software, the two voltages are converted into a single one. It may seem confusing that we have three sensors and two impedances just to end up with a single measurement, but remember you don't need to understand the details. Just recall that the lower the two impedances the better – and it also helps if the two are roughly the same magnitude.

In ECG measurement in particular, as long as we can detect the interval between heart beats, the impedance doesn't matter. Higher impedance will not really affect the accuracy of the *heart rate* calculation.

Two methods of minimising impedance are:

- Skin preparation (meaning cleaning with alcohol or a slightly abrasive gel).

- Use of conductive gel (to carry the electrical current across the gap between skin and sensor). The most convenient way of doing this is to use disposable pre-gelled self-adhesive electrodes (see figure 6).

Most users can still achieve good results without either of these. The alternative is to hold the sensors in contact with the skin using e.g. wrist bands. Use the SE23 snap electrodes in this case. You can use the plastic mounts, which go between the head of the cable and the snap electrode, but they aren't necessary. However if you don't use them, you must make sure that the sensor heads never touch each other. The plastic mounts will prevent this happening.

Impedances can be measured using the software – see section 4 below for details.

3.1.1 Artefact in EMG and ECG

In this context, artefact means a component of your measured parameter that does not originate from the source you are interested in. Think of it as contamination. For example, in measuring ECG we are interested in the electrical output of the heart, but if our measurement picks up activity from muscles then we have an artefact.

EMG and ECG are in some ways the same measurement – in both we are measuring an oscillating voltage. This voltage measured at the skin is complex in the sense that it does not have a single frequency of oscillation, but rather is made up of lots of different frequencies mixed together. Software applications make use of a process called digital filtering to simplify the signal. EMG and ECG use different choices of frequency range for this filtering (ECG uses a lower range). However the process is not perfect and inevitably a measurement of either ECG or EMG picks up activity of both heart and muscles. In other words, the one is a source of artefact for the other.

External sources of electromagnetic fields can also cause artefact. In practice this means electrical equipment and even the mains electricity supply.

The device driver contains a mechanism (called a notch filter) to remove mains electricity contamination, or interference. It should to be set to frequency of your country's mains supply, which in the UK is 50 Hz. See the Installation and Set-up Guide for more details. In practice this shouldn't matter, as unless you are using the EMG application with the wideband filter selected, all the applications avoid using this part of the spectrum anyway.

A much more likely source of interference is electrical equipment. How do you know if you have this kind of electrical contamination?

- In EMG it looks like you have stubbornly high muscle tension that you can't relax (because it isn't really muscle tension)

- In ECG, when you cannot see the usual prominent spikes that mark heart-beats. Figure 9 below shows what a relatively clean ECG signal looks like.
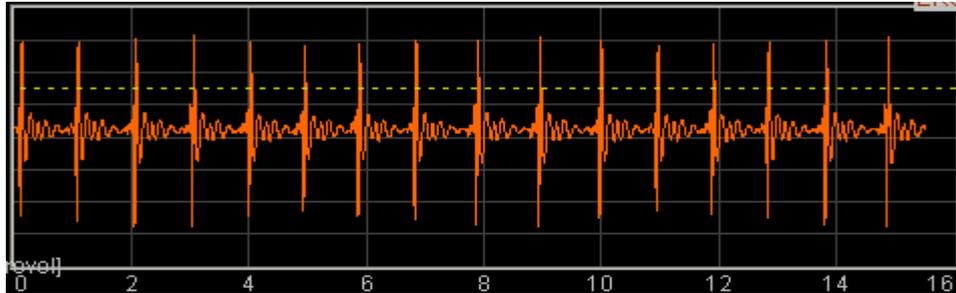

Figure 9 – Relatively clean EKG signal

3.1.2   How to Minimise Electrical Interference

If you suspect electrical interference, try to position the amplifier as far from electrical equipment as possible – including the computer itself. Similarly, keep the TP40 cables as free from possible interference sources as you can. This includes the USB cable that connects the GP8 unit to the computer – avoid having it lying alongside the TP40 cables. Also don't let the TP40 cables lie coiled or tangled up with each other.

A common source of trouble seems to be the mains adaptors (transformers) of some laptop computers. If you are using a laptop, try unplugging from the mains so that the computer runs on its battery power, to see if this makes a difference. If it is an issue the only solution generally is to run your biofeedback sessions on battery.

3.2 Basic EMG Application

Connect the three TP60 cables (figure 3) to inputs 1,2 and 3 (see figure 1). The order is significant – see the table in section 2 above. Attach snap electrodes before connecting to the body (they fit like press studs). You can either use pre-gelled self-adhesive snaps (see figure 6) or reusable gel-free snaps (figures 4 and 5) held to the skin using for example wrist bands.

Think of EMG as detecting the muscle tension between the two active sensors (white and black). The third sensor (ground) is less important, in terms of where it is placed. If you place the active sensors at either end of a single muscle, you will detect the tension largely (though not exclusively) from that one muscle.

In general the positions of the two active sensors can be interchanged with no effect.

You can of course attach the sensors wherever you want, but two commonly used and very useful placements are:

- Wrist to wrist (i.e. one active at either wrist, and the ground at either). This detects tension in the whole arm and across the shoulders, and also the hands. To some extent it also picks up chest and neck tension. One reason it's such a useful placement is that emotional tension commonly manifests in this group of muscles, especially the shoulders. Another reason is that it can distinguish chest-based breathing from abdominal or diaphragmatic breathing. If you

are using non-adhesive electrodes (gel-free) use wrist bands to hold them against the skin.

- Forehead (or frontalis muscle) – the three electrodes should be horizontally aligned with the green (ground) in the middle. This placement picks up tension from the whole head, especially the powerful jaw muscles. Again this is a useful reflection of emotional tension, though not breathing. You may also find that internal self-talk manifests as some tension, picked up with this placement. When using non-adhesive (gel-free) electrodes, use a head band to hold them in contact with the skin.

3.2.1 Sources of Artefact

See the general comments made earlier (section 3.1) on artefact in EMG and ECG.

Interference from electrical equipment is a common problem. Keep the amplifier and cables as far from electrical equipment (including the computer) as is practical. Keep the sensor cables apart from the USB and other electrical leads.

As explained, the electric field of the heart is a potential source of artefact in EMG measurement. In practice it is almost never a problem for placements where the two actives are the same side of the heart and roughly equidistant from the heart – e.g. forehead placement. For the wrist placement, however, it will be there. The heart beat generally shows up as a peak in the signal every heart beat. It is only apparent when the muscle tension is relatively low. It can be smoothed out to a large extent by the use of averaging (see the software application guides). In my experience it does not significantly detract from the effective use of EMG biofeedback.

3.3 EMG & Breathing Application

Connect the sensors as for the Basic EMG application – see section 3.2 above. In fact all of section 3.2 applies here too.

Both the wrist to wrist and forehead placements are useful for reasons given in section 3.2 above. Another placement useful for picking up upper chest breathing is trapezius to scalene (clearly some anatomical knowledge is required for this placement).

Breathing is detected using the temperature sensor (figure 8), placed just inside or just below the nostril. Hold the sensor in place using a small piece of surgical (microporous) tape. Connect the cable to input 4 (see figure 1). Clearly breathing through the nose (at least to some degree) is necessary for this to work. Some people breathe through both nose and mouth, which generally works fine. There is only a problem when the nasal passages are blocked. Before placing the sensor, check which nostril seems to be the clearest.

The software must calibrate to your breath, as described in the software application user guide.

3.3.1 Sources of Artefact

The sources of EMG artefact are the same as for the basic EMG application – see section 3.2 above.

Breath detection based on temperature is fairly robust, once calibrated (see the application user guide for a discussion of breath calibration). Speech will disrupt the air flow, and sniffs, sneezes etc. are likely to be interpreted as breaths of short duration.

3.4 HRC Application

Heart rate is detected via ECG. Connect the three TP60 cables (figure 3) to inputs 1,2 and 3 (see figure 1). The order is significant – see the table in section 2 above. Attach snap electrodes before connecting to the body. You can use either self-adhesive pre-gelled snaps or reusable gel-free snaps. The latter is in my experience almost always perfectly adequate, indeed since we only need to

detect the heart beat there is no disadvantage at all.

Any placement in which the two active sensors are either side of the heart should work. Placing the sensors on the wrists is usually the most convenient.

Unlike with EMG, interchanging the two active sensors (white and black) does make a difference. Place the white sensor on the left wrist, and black on the right. Look at the raw ECG trace in the software application (support window) and you should see a prominent upward deflection every second or so, which crosses the yellow dotted threshold line. Figure 9 above shows you what this looks like. If the trace looks upside-down (i.e. with a bigger deflection *below* the main body of the signal) then swap the the two actives over, and remember this for future occasions.

Breathing is detected using the temperature sensor, placed just inside or just below the nostril. Hold the sensor in place using a small piece of surgical (microporous) tape. Connect the cable to input 4 (see figure 1). Clearly breathing through the nose (at least to some degree) is necessary for this to work. Some people breathe through both nose and mouth, which generally works fine. There is only a problem when the nasal passages are blocked. Before placing the sensor, check which nostril seems to be the clearest.

The software must calibrate to your breath, as described in the software application user guide.

3.4.1 Sources of Artefact

Again see the general comments made earlier (section 3.1) on artefact in EMG and ECG.

Interference from electrical equipment is generally less of an issue than with EMG. However if you don't get a clear ECG signal follow the same advice: keep the amplifier and cables as far from electrical equipment (including the computer) as is practical. Keep the sensor cables apart from the USB and other electrical leads. If you are using a laptop, try disconnecting the mains transformer and running on battery.

For ECG, muscle activity is the potential source of artefact. If strong enough it can swamp the heart signal so that the heart beat cannot be detected. In practice this means that the user needs to sit in a fairly relaxed state. Gentle movements are mostly tolerated as long as they are not sustained in time. More forceful movements do lead to a loss of the heart beat for a few seconds but generally the software recovers once the user settles again.

Breath detection based on temperature is fairly robust, once calibrated (see the application user guide for a discussion of breath calibration). Speech will disrupt the air flow, and sniffs, sneezes etc. are likely to be interpreted as breaths of short duration.

3.5 Heart Rate Data Collection Application

Use the same set of cables and sensors as for heart rate, in the HRC application, and connect them to the amplifier in the same way. The HR data collection application does not monitor breathing so you don't need to connect the breathing (temperature) sensor.

Sources of ECG artefact are the same as described in section 3.4.1 above.

3.6 Breathing Application

Breathing is detected using the temperature sensor (figure 8), placed just inside or just below the nostril. Hold the sensor in place using a small piece of surgical (microporous) tape. Connect the other end of the cable to input 4 (see figure 1).(see figure 1). Clearly breathing through the nose (at least to some degree) is necessary for this to work. Some people breathe through both nose and mouth, which generally works fine. There is only a problem when the nasal passages are blocked. Before placing the sensor, check which nostril seems to be the clearest.

The software must calibrate to your breath, as described in the software application user guide.

3.6.1 Sources of Artefact

Breath detection based on temperature is fairly robust, once calibrated (see the application user guide for a discussion of breath calibration). Speech will disrupt the air flow, and sniffs, sneezes etc. are likely to be interpreted as breaths of short duration.

3.7 Infra-red Neurofeedback Application

The infra-red temperature sensor (figure 7) is used. Connect the socket to input 4 (figure 1).

Typically the sensor is placed over the forehead, firstly because hair will tend to block the infra-red radiation, and secondly because of neuroanatomy: the pre-frontal cortex behind the forehead is the brain's "executive control" region, a very useful place to train, and also responsive to our conscious efforts. I recommend placing the sensor over the centre of the forehead, although it is possible to place it anywhere else on the forehead.

There should be an air gap between the sensor and the skin, and a channel for the movement of air. This is what the sensor mount achieves.

At the current time of writing the manufacturer has not finished developing a head mount for the IR sensor, so I am using a home made version. The IR sensor should be positioned between the two sponge blocks, where it will be held in place by velcro. Have the head band fastened loosely, so that the tension doesn't significantly compress the sponge blocks and you maintain the air gap.

3.7.1 Sources of Artefact

Draughts of air over the sensor will cause the signal to dip. For this reason, it is recommended to keep the head relatively still. Also, head movements may cause subtle changes in blood flow which may register as changes in the signal.

Excessive sweating may cause condensation to form on the sensor, impeding accurate measurement.

3.8 IR Neurofeedback with Breathing Application

As with the HRC and EMG & Breathing applications, the breathing sensor is the temperature sensor (figure 8), placed just inside or just below the nostril. Hold the sensor in place using a small piece of surgical (microporous) tape. Connect the socket to input 4 (see figure 1). Clearly breathing through the nose (at least to some degree) is necessary for this to work. Some people breathe through both nose and mouth, which generally works fine. There is only a problem when the nasal passages are blocked. Before placing the sensor, check which nostril seems to be the clearest.

The software must calibrate to your breath, as described in the software application user guide.

The infra-red temperature sensor (figure 7) is used. This time connect it to *input 5* (figure 1). As with standard IR neurofeedback application, the location for the sensor is the forehead. See section 3.5 for details of attaching it.

3.8.1 Sources of Artefact

For the IR sensor, the sources are those listed in section 3.5.1.

Breath detection based on temperature is fairly robust, once calibrated (see the application user guide for a discussion of breath calibration). Speech will disrupt the air flow, and sniffs, sneezes etc. are likely to be interpreted as breaths of short duration.

3.9 Skin Temperature Application

Skin temperature biofeedback is a way of training activity in the Autonomic Nervous System (ANS). The usual sensor site for skin temperature training is one of the fingers, since temperature changes there are normally caused by alterations in blood flow triggered by ANS activity.

Connect the temperature sensor (figure 8) socket to input 4 (figure 1). Tape the temperature sensor to the finger using surgical (microporous) tape, as shown in figure 10. Run the sensor (and the tape) parallel to the length of the finger, and cover the bulb at the end of the sensor cable with tape.

Figure 10: Skin temperature sensor placement

3.9.1   Sources of Artefact

Air currents over the sensor (causing cooling) are the most common source of artefact. Avoid draughty environments for training, or put a loose thin cover over the hand.

Train somewhere with a stable ambient temperature, not too hot or too cold. We want to monitor changes associated with emotional and mental states, not real temperature regulation. Likewise, train only when you yourself are at a stable temperature. If you've just come in from a cold environment, the measured changes are likely to reflect your body's adjustment to the new surroundings.

Taping around the girth of the finger rather than along the length can cause restriction of the blood flow and this will affect the measurements.

4 Battery and Impedance Checking

You can check the battery and impedance from the launcher application. On the set-up tab is a button, 'Start Battery and Impedance Check Application'. This starts a BioEra design, shown in figure 11 below.

Figure 11: Battery and impedance checking application

5 Care of the Equipment

Damage to the equipment (especially sensor cables) can and does happen. Please follow these guidelines to ensure the maximum lifetime of the equipment.

- Take care to insert batteries with the correct polarity – inserting them the wrong way round can damage the amplifier. Also be careful when removing the batteries – you can use a ballpoint pen to lever them out.

- Never bend cables sharply. This applies especially to the TP40 EMG / ECG cables. Store cables coiled into loops. Don't bend the amplifier's USB cable sharply at the point of origination on the amplifier.

- Never pull on a cable, especially the sensor cables (for example to detach them from the skin). Instead, take hold of the sensor head (in the case of the EMG/ECG leads) or pull the tape (in the case of the temperature sensor). Likewise don't pull the cables to detach them from snaps.

- Take care to minimise rubbing the surface of the SE23 snap electrodes.