Hardware Set-up Guide
J & J C2+ Amplifier

1 Introduction

This document describes how to set up the C2+ 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 C2+ 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.
- Skin Conductance – used in the Galvanic Skin Response (GSR) application.

The C2+ amplifier does not support an infra-red sensor, so the infra-red neurofeedback applications do not work with the C2+.

There are two versions of the C2+ amplifier – one being capable of reading 12 channels of data, the other 6. In terms of running the Mind-Body Training Tools applications, there is no difference. The 12 channel unit has four input sockets at the front (see figure 1) while the 6 channel model has two.

Each input is capable of reading different types of physiological data, including EMG, ECG, EEG and temperature, at sample rates of up to 1024 per second. EEG is currently not used in any Mind-Body Training Tools 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 C2+ requires four AA 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 – C2+ amplifier

Figure 2 – C2+ 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	Figure	Description
Set of 3 EMG cables (MC-5SGW)	3	Used for EMG (muscle tension) and may also be used for ECG (for heart rate).The white and black leads are known as the active sensors while the green is the ground. Joined at a single socket.
Gel-free ECG cables (MC-5D)	4	Designed primarily for ECG (for heart rate) but may also be used for EMG. They do not require snaps and are used gel-free. Joined at a single socket.
Snap electrodes (SE23)	5	These snap into the heads of the MC-5SGW cables above. They can be used for both EMG and ECG. Reusable.
Disposable pre-gelled electrodes	6	Alternative to SE23 snaps above. They give more accurate readings.
Temperature sensor + skin conductance sensors (MC-6SY)	7	Temperature sensor is used for breath measurement in the HRC and breathing applications, and in the skin temperature application. Skin conductance sensors are used in the GSR application.

All the above cables connect to either input A or B (figure 1) depending upon the application.

Figure 3 – Set of three cables for EMG. The heads (upper right) need to be fitted with snaps (see figures 5 and 6).

Figure 4 – Gel-free EKG sensors

Figure 5 – Gel-free reusable snap electrodes for use with cable MC-5SGW

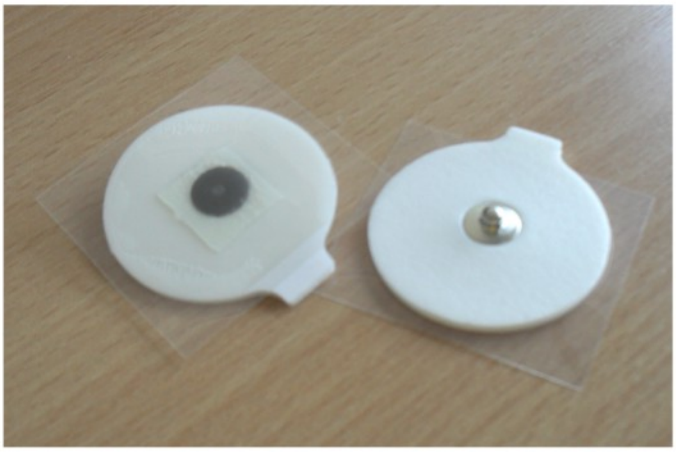

Figure 6 – Disposable pre-gelled self-adhesive snap electrodes for use with MC-5SGW

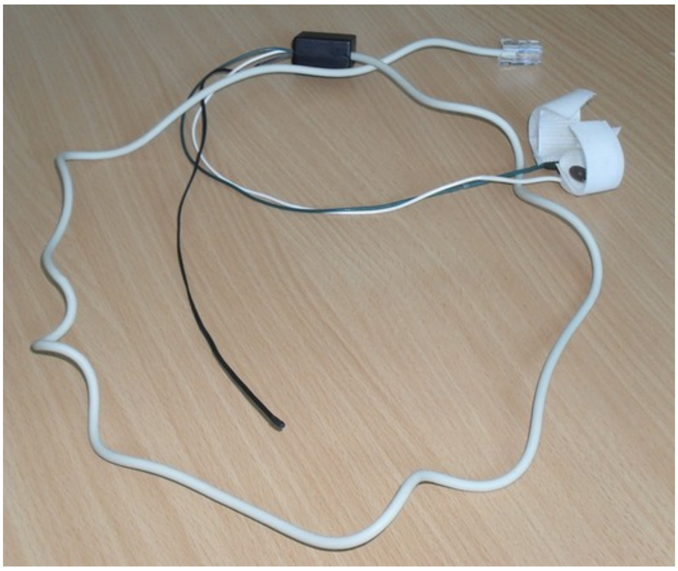

Figure 7 – Temperature sensor (black cable) and skin conductance sensors (white velcro straps)

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 – the first between the white and green sensors, the second between the black and green. 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 must make sure that the sensor heads never touch each other.

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 8 below shows what a relatively clean ECG signal looks like.

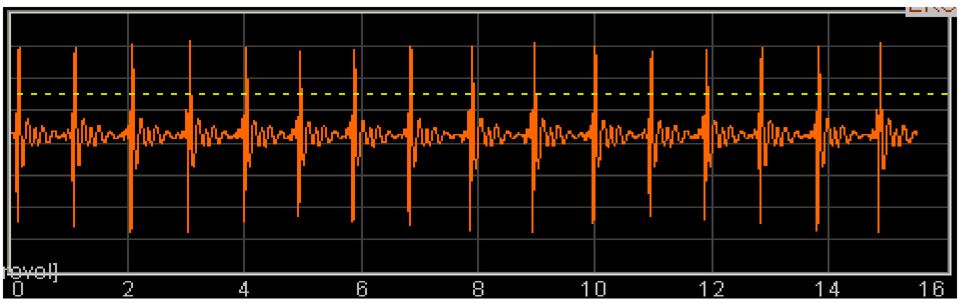

Figure 8 – Relatively clean EKG signal

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 EMG/ECG cables as free from possible interference sources as you can. This includes the USB cable that connects the C2+ unit to the computer – avoid having it lying alongside the EMG/ECG cables. Also don't let the EMG/ECG 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

You can use either the MC-5SGW cable or the MC-5D gel-free sensor cable. The former must be used with snap electrodes – you can either use pre-gelled snaps (see figure 6) or gel-free snaps (SE23, figure 5) held to the skin using wrist bands or a head band. The former will give more accurate readings. Although designed for ECG (heart rate), the MC-5D can also be used for EMG. It is less accurate than using gelled electrodes.

Whichever cable you use, connect it to input A of the C2+ unit.

When using the MC-5SGW cable, the two active sensors are the white and black heads, while the green head is the ground. When using the MC-5D cable, there are two sensor housings, each incorporating an active and a ground.

Think of EMG as detecting the muscle tension between the two active sensors. The position of the ground sensor is less important. 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). If using the MC-5SGW the three electrodes should be horizontally aligned with the green (ground) in the middle. If using the MC-5D cable, place the sensors at either side of the forehead. 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 may be a problem, though unlikely if using shielded cables such as those in figure 5. If you suspect interference, 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

As with the basic EMG application either of the MC-5SGW or MC-5D cables can be used. Most of section 3.2 applies here too. Whichever cable is used, connect it to input A of the C2+ unit (see figure 1).

Both the wrist to wrist and forehead placements are useful for reasons given in section 3.2. 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 7), 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 B (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. For comfort, the weight of the rest of the cable and other sensors must be managed. I suggest tucking it inside of clothing.

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. The MC-5D cable was designed for gel-free detection of ECG and is generally most convenient to use, however you can also use the MC-5SGW cable with either pre-gelled snaps or reusable gel-free snaps. Whichever cable is used, connect it to input B of the C2+ unit (see figure 1).

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. If using gel-free sensors, hold them in contact with the skin using wrist bands.

Unlike with EMG, interchanging the two active sensors does make a difference. Place an active sensor at each wrist. 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 8 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 their locations for future occasions. (If using the MC-5D sensors it is convenient to label them so that you can distinguish between left and right.)

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 socket to input A (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. For comfort, the weight of the rest of the cable and other sensors must be managed. I suggest tucking it inside of clothing.

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, 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 A (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. For comfort, the weight of the rest of the cable and other sensors must be managed. I suggest tucking it inside of clothing.

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 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.

Figure 9: Skin temperature sensor placement

Use the temperature sensor shown in figure 7. Connect the socket to input A (see figure 1).Tape the temperature sensor to the finger using surgical (microporous) tape, as shown in figure 9 above. 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.

3.7.1 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.

3.8 GSR Application

GSR biofeedback is a means of working with the Autonomic Nervous System (ANS). The usual sensor sites are two of the fingers.

Use the sensor cable shown in figure 7. Connect the socket to input A (see figure 1). The two white velcro fastenings are wrapped around adjacent fingers, one per finger, not so tight as to restrict blood flow (so that the pulse can be felt).

The temperature sensor which is part of the same cable is not used.

3.8.1 Sources of Artefact

Typically when working with GSR we are interested in relative change of the signal rather than the absolute values being measured. As long as the sensors are stably in contact with the skin the measurement should be meaningful, but movement of the sensors will cause artefact. Movement of the hand should be limited.

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 10 below.

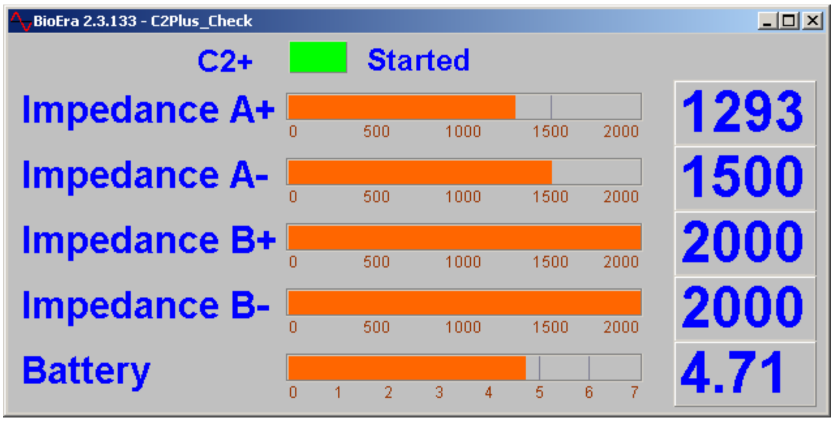

Figure 10: Battery and impedance checking application

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 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.