Physiometry 101

Data Collection

"What connector do I need to connect your 1010 to my computer?"

So you can use physiometry to measure, to sense something about your subject. Now, what? In the old days, researchers could dimly see, perhaps, the electrical signature of the ECG in pale green, on a dusty hot oscilloscope. Better still, he or she could connect their signal to a strip chart recorder, and they would have a record on paper of what the ECG signal looked like. And pretty soon, he or she would have hundreds of rolls of chart paper, each a record of ECG signals! Now we have complex computer systems, and instead we have hundreds of files...

But you want to be able to see, to save, and to review the results of your exercises in physiometry, so you can analyze your data and theorize and postulate the latest... Getting your physiometry data into a form that can be easily seen, and can just as easily be looked at again, whenever you want, that is the task this article explores. And, to answer the question asked at the end of the previous article, it is *electrical signals* that are most easily recorded to begin with.

There are a few important steps involved in being able to record your physiometry data. Overall, we can refer to this process as data collection.

Step 1 -- the sensed signal in electrical form

Electrical signals that naturally occur in the subject are called bioelectric signals. Getting access to these signals is usually fairly easy. Some sort of electrodes need to be connected to the subject, and the leads from these electrodes should theoretically supply the signal you are after. For many types of subjects, very fine needle electrodes carefully penetrating into live tissue will supply the best signal. For human subjects, skin surface electrodes are probably the best you can do, and an entire book could be written that includes all the details to be grasped when instrumenting a human subject for bioelectric signals. You also need to know what location on the subject (the electrode site) will supply the signal you are after, and then you place electrodes at that site. Either way, if everything goes according to plan, the bioelectric signal of interest can be sensed from these electrodes and the leads connected to them

The use of transducers follows a similar plan. You locate the site on the subject for the transducer that should supply the best signal. The tricky part is the actual attachment of the transducer to your subject. Generally, some mechanical means (a strap, some tape, etc.) will be necessary to hold the transducer in place. In addition, the transducer may require a specific tension/pressure/direction in order to best detect the parameter to be sensed. All this needs to be taken into account when mechanically attaching the transducer to the subject. And, for some transducers, some steps may need to be taken to shield the transducer from ambient influences. But again, if everything goes according to plan, the leads from the transducer will supply the signal of interest.

Step 2 -- signal conditioning (amplifying and filtering)

Having the signal you want on the leads from the transducer or electrodes is only the (important) first step. Transducer output signals can range from 20 to 100 mV. Bioelectric signals can be 1mV, often smaller. Note that the input range of most analog to digital systems (more below) is measured in Volts. Your sensed signal will usually need to be made bigger, sometimes a lot bigger; it must be amplified.

Not only that, but the signal you sense may include a lot of other "noise", often referred to as artifact. The biggest noise source will be the 60 Hz. (or 50 Hz.) frequency that all Mains power systems function with. Unless everything within a few hundred feet is battery operated, this is just something that needs to be addressed. In addition, some artifact may also be other bioelectric signals present in your subject that you wish to ignore. There are generally multiple bioelectric signals in most subjects, and your electrodes can easily pick up more than one of these.

The signal conditioning will need to perform two basic functions. The signal sensed from the electrodes or transducer will need to be amplified, often substantially. In addition, some sort of filtering will need to be supplied to the amplified signal to allow you to focus just on the specific signal you are after. There will generally not be a 'one size fits all' solution to this; each signal conditioner will need to be carefully matched to both the signal being sensed, and the means used to supply it to the amplifier. And clearly, one signal conditioner will be necessary for each channel of physiometry in your system.

At the output of the signal conditioner, you hope to have your signal of interest, maybe 1-2 volts in size, with as much extra stuff as possible filtered out.

Step 2a -- impedance equipment

The use of impedance equipment follows a similar pattern as the use of electrodes for sensing bioelectric signals. Impedance sensing always uses electrodes to connect to your subject. The difference is that impedance equipment uses electrodes both to supply a signal to the subject, and also to measure the response, the modification of that supplied signal as a result of the subject. In most cases, the necessary signal conditioning is actually built into the impedance equipment. In other words, the signal conditioning is usually a part of the overall impedance solution.

Step 3 -- analog to digital conversion

Digital computers offer huge benefits over oscilloscopes or strip chart recorders! You no longer need a large roll of 5" wide chart paper to hold a one hour segment of high resolution ECG. Hundreds or thousands of such records can be stored on a small USB memory stick.

But digital computers are best at handling digital data. This has forced two important facts of life on researchers. First, some form of Analog to Digital Conversion process must be used to translate your precious physiometry data from its natural Analog form, into a recognizable Digital value. The second fact of life is that, by far, voltages are the most easily digitized. This explains why your physiometry channels will end up as a high level (on the order of 1-2 Volts) voltage. You will often need some means to scale that voltage back to the original measurement. Still, it is a voltage value that you actually need so you can digitize it.

The analog to digital conversion process performs exactly what it implies. You supply an analog value, a voltage, and this process 'samples' that analog voltage, and then converts the sampled voltage into an accurate, digital value. This sounds simple, but this whole process involves a few variables that must be decided. You can talk about sample resolution, and 12 or 16 bits resolution are the most common for physiometry. And 12 bits resolution supplies 1/4096 resolution, or a resolution of 1.2 mV for a 0-

5Volt input range. Sample frequency is probably more important. The actual characteristics of what you are measuring as it varies over time; that information may favor a certain, minimum sample frequency. For example, a 250 Hz. sample frequency can supply a fairly high resolution ECG signal. If you use a slower frequency you may lose details you want to see. If you use a faster frequency, more memory will be required for an hour of data, and that may or may not be a problem. And, if you have multiple channels, you need to decide if you want to sample everything at the same sample frequency or not. Skin Conductance changes at a fairly slow rate, and a 250 Hz. sample frequency is surely overkill for this physiometry data channel.

But you should have, at the end of this process, a digital value that can represent the original analog value you measured from your subject. In most cases, this will not be just a single value. Usually, the result will be a series of values, measured a fixed increment of time apart, and this series of values will be the physiometry result you are after.

Step 4 -- saving the data

This series of values, each one of which is a digital representation of your precious analog physiometry data, is made 'permanent', when it is saved in some form of memory. This process also sounds simple. However, the file format and the overall packaging of our entire segment of data, especially if multiple channels are involved; this all depends on the specifics of both the computer system and control software that, together, are managing the data saving process. These are not meaningless details! We absolutely need to be able to identify our physiometry data, wherever and however it was saved!

Step 5 -- view and review

When all is said and done, you want to see your data. And you want to be able to see it multiple times, if need be. And how do you want to see it? Squeezing a 1 hour plot of ECG into the plot area will show a thick, fuzzy line occupying most of the plot area with no other details. You would need to only plot a one second segment of ECG to see meaningful detail. And if you can do this, you also need to have some means of moving around in the data file, in order to see more than just the first second of data.

Unless some accepted common structure is used, the same data collection program will usually both save the data, and also supply the means to later load that data back in for review. Controls will allow the width of the plot area to be set, and also help move through the file, so you can view all the data it includes. Printing the window of data, or even copying data to the clipboard for inclusion in other programs, both are helpful capabilities.

But it is the data collection program, working with the resources supplied by the computer; both of these work together to allow you to save, view and review your precious physiometry data.

Ambulatory vs. Desk-top

An ambulatory recording system refers to a recording system that is both compact and sufficiently self-contained to be able to be placed on an 'ambulatory' (free ranging, unconstrained) subject, who wears the recorder as they go through their normal life activities. Ambulatory recorders include connectors for the electrodes and/or transducers. These recorders also include all of the systems mentioned above. Signal conditioning, analog to digital conversion, data saving and data memory -- an ambulatory recorder has all these functions built-in. Generally, you cannot see the recorded physiometry data until after your recording session is complete. After your testing is done, you connect the ambulatory recorder to a computer, download and save the data, and only then can you load your data in and view what you just recorded.

For an ambulatory system, the data is actually saved twice; inside the recorder as it is being recorded, then a second time later as the recorded data is downloaded to a computer and then saved. A desk-top recording system handles this data differently, and routes the converted physiometry data directly to the computer, where it is both displayed and saved as it is being recorded. The desk-top system includes most of the steps indicated above. A compact housing holds signal conditioning for the supported channels, as well as the analog to digital conversion function. But from there, the data is sent directly to the computer. It is the software program running on the computer that manages the plotting and saving of the data, even as it is being recorded.

Which system is best? The better question is which system is most appropriate for your studies. Dest-top systems are seldom small, and also assume a direct connection to a computer, and so the amount of subject motion allowed is far more limited than with an ambulatory system. Also, if your research requires direct visual access to the data as it is being recorded, then the desk-top system is usually your only option.

Conclusion

Deciding how to sense your physiometry data is really only the first step in the process of actually being able to record and review that data! The process of getting your physiometry data from your subject, into a file on your computer hard drive, and then being able to view it whenever you want -- that is the data collection process. It is not simple, and a number of details need to be addressed along the way. We have received requests like the one included at the top. But there is far more involved than just plugging a transducer into a computer. Hopefully this discussion has made that clear!