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Editorial

# Don't assume that your equipment is doing what you think it is

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## Abstract

A perennial problem encountered by both novices and experienced people using psychophysiological recording equipment and then using the displays as the basis for biofeedback and neurofeedback is that the equipment is frequently not doing what the users think it is. Hardware and software are frequently glitchy and setting the devices incorrectly makes matters worse. The key question to answer is whether the device reliably produces a display clearly related to the physiological signal produced by the person being recorded. The editorial emphasizes the need to view a raw signal so relationships between the physiology being recorded and the display can be accurately assessed. Seven key questions users of psychophysiological recording and biofeedback/neurofeedback equipment need to answer are delineated. They include: (1) Are the sensors mounted optimally for location and orientation, (2) Are the sensors mounted well enough to pick up a good signal, (3) Is the device's bandwidth set appropriately, (4) Is there noise in the signal, (5) Does the display accurately reflect changes in the signal, (6) Does the display change when the physiological signal does, and (7) Is the display set so users can accurately assess the signal? Users are encouraged to get the training they need to do a great job when performing recordings.

## Keywords

Recording Errors, Fetal Flaws, Psychophysiological Recording, Biofeedback, Neurofeedback.

## Introduction

A perennial problem encountered by both novices and experienced people using psychophysiological recording equipment and then using the displays as the basis for biofeedback and neurofeedback is that the equipment is frequently not doing what the users think it is. Hardware and software are frequently glitchy and setting the devices incorrectly makes matters worse. The following are a few of the key areas which need to be checked every time a recording is made. The key question to answer is whether the device reliably produces a display clearly related to the physiological signal produced by the person being recorded.

Note that the raw signal (or as close to it as the device permits) – rather than some averaged / integrated version - must be viewed when checking the quality of the signal and any display based on it as integrated signals change too slowly to show common artifacts in the signal.

Here are several questions to consider:

1. Are the sensors mounted optimally for location and orientation? This is crucial! If the sensors are not in the right place to pick up the physiologically based signal you want, no amount of processing will help. This is a common problem for people doing EEG recordings using only one active and one reference (usually ear clip) sensor. If the sensor is not oriented properly, it can not pick up the signal properly. For example, if the calf muscle is being recorded for surface muscle tension (SEMG), many people position the sensor across the muscle (horizontally) rather than along it (vertically). As the differential amplifiers in SEMG recording systems depend on picking up signals as muscles depolarize during contraction, they only pick-up a relevant signal when the active electrodes are placed along the length of the muscle. If placed across it, all they pick up is noise.

2. Are the sensors mounted well enough to pick up a good signal? This is frequently a matter of impedance between the skin and the sensor for muscle tension and EEG. Most high-quality recording systems have impedance checks which let the user know if the sensor is attached well enough to record a good signal. Some systems cease recording if the impedance becomes too high for a good signal. If there is no signal quality check screen or system, it is up to the user to check the sensor's impedance. Impedance meters tend to cost over 350 US dollars. The alternative is to have considerable expertise in recognizing artifacts in the signal and ensuring that the display is showing intensities proportional to some objective gage such as discussed below.

Respiration belts are frequently mounted too loosely to pick up changes in breathing or are placed incorrectly on the body. This is a common problem when recording chest breathing among women as the belt needs to be mounted either above or below the breasts depending on where the most change in circumference with inhalation occurs. After the optimal location for the belt is determined, the user needs to pull the belt gently and watch for a proportional change in the display. The person being recorded should take a deep breath and a shallow breath with the display showing a clear difference. The raw respiration signal must be displayed as a display of respiration rate obscures problems with the signal itself.

Photoplethysmographs used to record the pulse from a finger frequently don't work

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consistently due to low amounts of blood flow to the finger and movement artifacts. It is best to record from the largest digit available such as the thumb as the change in blood flow between pulses is more distinct. Subjects have to keep the digit being recorded very still throughout the recording. If an alternative way of recording the pulse, such as wrist to wrist sensors, is available, it should be used. Regardless, the display needs to be checked by comparing the pulse the user feels at the wrist with the reading being displayed. This requires looking at the raw pulse signal rather than a heart rate or heart rate variability display as these calculated displays obscure the fact that the actual pulse is not being recorded reliably and consistently

3. Is the bandwidth of the device set appropriately? Bandwidth refers to the frequencies of interest each physiological signal generates. For example, the bandwidth for alpha EEG signals is about four to eight Hertz (cycles per second). There will be different amounts of power (intensity) at each of the frequencies. Each muscle produces a typical profile of power at various frequencies at each level of tension. Typically, the frequencies of interest which produce the power representative of overall tension in the muscle range from about eight to five-hundred Hertz. Most psychophysiological recording systems have a default bandwidth which permits recording of only a portion of the signal reaching the sensors. If the system's bandwidth is set to the wrong setting so important parts of the muscle's power is not recorded, then the display shows less power than the muscle is producing at that level of tension. For example, if the device's bandwidth is set to 100 – 200 Hz, but most of the muscle's power is between 300 and 500 Hz, the display will show far less power – which equates to "tension" in most people's minds – than is actually the case.

4. Is there noise in the signal? This usually includes heartbeat artifacts, motion artifacts, and electrical noise from poor connections. The key is to be able to recognize a good quality signal and differentiate it from problems such as the display breaking up during changes in the signal caused by tensing and relaxing a muscle (etc.), movement artifacts (in which the entire baseline of the signal changes) as well as repeated, relatively high deflections in the display caused by electrical noise and heart beat artifacts, etc. Again, the raw (or nearly raw signal) has to be viewable on the display to determine signal quality. Long integration times obscure spasms and bad signals. It takes extensive training to learn to recognize movement artifacts and other sources of noise. Too may practitioners spend much of their careers feeding back noise because they can't differentiate between noise and a good signal. People performing psychophysiological recordings need to do their homework so they become familiar with what noise looks like in the various signals being recorded.

5. Does the display of the raw signal accurately reflect changes in the physiological signal? Most especially, does the device produce nearly the same numbers when a signal is nearly repeated? Users need to know whether the device is calibrated so the magnitude of the physiological signal is accurately reflected by the display. Most devices either come with a calibration system or need to be calibrated to ascertain whether the signal displayed is accurately related to the signal being

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produced by the person being recorded. It is very easy to ignore the technical portion of manufacturers' instructions for checking calibration. In cases where no calibration system is included with the device, it is usually fairly simple to check whether a device is producing a realistic, repeatable display. For example, the number of microvolts produced by most muscles in the body while at rest (baseline) and near maximum tension are well known and can be found in the literature. Baselines for resting muscles in a normal person observed from raw (not integrated/averaged) signals should be below five microvolts and be very consistent without peaks (other than heartbeat artifacts) going above five microvolts. The readings should be very similar between recording sessions unless some intervention has been made even if the subject has begun habituating to the equipment. The number of microvolts displayed for surface muscle tension signals during tensing should be very similar when about the same amount of tension is generated by the subject. As there is a consistent relationship between how hard a person squeezes a device such as a dynamometer and the number of microvolts produced by the major muscle used to activate the device, the number of microvolts displayed should be within a few percentage points when the dynamometer is squeezed to the same moderate (not maximum) reading. The psychophysiological recorder's display cannot vary by more than a few microvolts (e.g. show 20 microvolts one time and 100 microvolts another) when the reading on the dynamometer's dial is the same. The display must show the number of microvolts expected of moderate tension in that specific muscle as defined in the literature. Several devices currently on the market show a few microvolts at one reading then over a thousand in a second reading with the same pressure on the dynamometer. Dynamometers of sufficient accuracy for this purpose cost between ten and thirty-five US dollars.

6. Does the display change when the physiological signal does? In other words, is the device actually recording the subject or just producing a realistic display? All too often a very realistic display of every physiological signal being recorded – especially heart rate – is actually a copy of signals recorded earlier or generated by the system being used. This is occasionally caused by glitches in the software but more often by users themselves who haven't read the manufacturer's instructions for how to start and record the display of the physiological signals. The person doing the recording must check that the display changes when the signal does. This requires having the subject change each signal such as respiration rate and depth, muscle tension, etc. The change should be reflected in the display of the raw signal immediately.

7. Is the display set so the recording can be adequately assessed? Typical visual displays of raw signals provided by modern psychophysiological recording (and biofeedback/neurofeedback) equipment consist of sweep speed, offset, and amplification of the signal. Sweep speed is how quickly the signal traverses the monitor from left to right. It must be set slow enough so sufficient details of the signal can be observed to determine whether there are artifacts in the signal but fast enough so changes in the signal can see seen in detail – as when a muscle contracts and relaxes. Users may need to change the sweep

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speed for each of these purposes. Amplification is equivalent to the volume. It has to be set high enough to see details of the raw signal but not so high that the upper and lower portions of the signal go off the top and bottom of the display when the signal's power changes. Offset is the vertical location of signal on the display. If it is set too low or too high, part of the signal is cut off when the signal's intensity changes.

## Conclusion

Users of psychophysiological recording devices should consider learning enough to do a great job when performing recordings. If you want to be certain you are doing an optimal job recording psychophysiological signals of many types, you may want to take a course in psychophysiological recording, read a book covering many different parameters, or read a few articles covering recording methodology for the specific parameter you want to record. You could even (gasp), read the manufacturer's instructions for the system you are using. Articles on recording methodology for specific signals can be identified through searches of the web. The Behavioral Medicine R&T Foundation offers excellent courses such as "Psychophysiological Recording", "Basic EEG Biofeedback/Neurofeedback", and "Basic Biofeedback" which cover recording methodology in detail. Books such as "Pain assessment and intervention from a psychophysiological perspective" also discuss recording methodology.