<u>Sensor Related Factors and Fidelity of the sEMG Signal©</u>

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<u>Electrode</u> – The metal surface of the sensor which makes electrical contact with the skin.

<u>Sensor</u> – The unit that contains the electrodes and the electronic circuitry for differential amplification of the EMG signal and reduces the contribution of various noise sources.

<u>Noise</u> – Those electrical signals which are detected by the electrodes and the remainder of the sensor, but do not originate in the muscle below the sensor.

The following table outlines the relationship between sensor design, user preparation, sEMG signal, and various noise sources. Note that the sensor application and the skin preparation play important parts in detecting an sEMG signal of high fidelity. The dominant factor in the User Preparation is the location on the muscle where the sensor is attached. The proper sensor location can enhance the amplitude of the sEMG signal and reduce the crosstalk much more dramatically than the design of the sensor. Thus, the signal fidelity is in large part influenced by proper choice of sensor location – a decision that is left to the user.

Key to table - independent variable -- Sensor Design and User Preparation
dependent variable -- Signal and Noise Source

▲ dependent variable increases as the independent variable increases
▼ dependent variable decreases as the independent variable increases
▲▼ the dependent variable either increases or decreases

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(The larger arrows indicate a more dominant factor.)
(Green indicates a favorable occurrence, red indicates an unfavorable occurrence.)

ACTIVE DIFFERENTIAL SENSOR	SIGNAL	NOISE SOURCES				
		Cross-Talk	Movement Artifact	Baseline	Line radiation (50, 60 Hz)	EKG
Sensor Design						
Inter-electrode spacing	▲	▲				▲
Electrode area		▲		▼		
Electronics quality				▼	▼	
Sensor construction				▼	▼	
User Preparation						
Location on muscle	▲▼	▲▼				
Skin preparation	▲					
Liquid electrolyte				▲▼		
Hydrophilic-gel electrolyte			▲			
Sensor orientation with fibers	▲▼					▼
Location and size of reference electrode					▲▼	▲
Proximity to heart						▲

EXPLANATION

Inter-electrode spacing – The distance between the electrodes renders an increase in the amplitude [1] of the signal (which is beneficial) as well as an increase in the cross-talk sensitivity (which is detrimental) [unpublished work]. Between the two, it is advisable to reduce the cross-talk sensitivity, because cross-talk is virtually indistinguishable from the EMG signal. With greater inter-electrode spacing, there is a greater chance of detecting the EKG signal if the sensor is placed on the chest or upper back muscles.

Thus, smaller inter-electrode spacing is preferable. Also, the electrodes should have a fixed spacing in order to provide consistent and repeatable measurements of signal amplitude. Delsys uses a spacing fixed at 1.0 cm for this and other reasons.

Electrode area – The larger the area the greater the amplitude of the cross-talk signal. This occurs partially due to the encroachment of the electrodes on the nearby muscles. The baseline noise decreases with increasing electrode area [2].

Electronics quality – Electronics components with higher tolerances generate less baseline noise and are better able to reduce (possibly eliminate) the line radiation noise (50 or 60 Hz) enabling a more accurate performance.

Sensor construction – Features such as surface shielding, component layout, and ground-plane geometry can reduce the baseline noise and the line radiation noise.

Location on muscle – If the sensor is placed:

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1) Near the innervation zone – the amplitude of the sEMG signal will decrease because cancellation occurs among the action potentials which propagate in opposite directions. The bandwidth of the signal will increase because the subtraction of action potentials moving in opposite directions yields residuals that have sharper transition in the time course of the signal.

In most large muscles, the innervation zones are located at the perimeter of the muscle or near the tendon- muscle interface [3].

2) Near the tendon – The amplitude of the sEMG signal will be relatively lower because the number of muscle fibers and the diameter of the muscle fibers are reduced in this region. Consequently the there are fewer action potentials that contribute to the sEMG signal and those have lower amplitudes.

3) Near the perimeter of the muscle – In most muscles, especially in the larger muscles, the amplitude of the sEMG signal will be relatively lower because there are fewer fibers in this region. Sensors located in this region detect an increased amount of cross-talk from adjacent muscles when they are active, which is likely to be so during most contractions.

PLACE sensor in the MIDDLE of the muscle surface – This location lies between the innervation zones (near the perimeter of the muscle) and the tendon- muscle interface. It satisfies the above considerations in most large muscles. In smaller muscles, such as those in the hand, there is no choice as to where to locate the sensor.

Skin preparation – The oils and debris that normally accumulate on the skin must be removed in order for the ionic exchange to occur effectively between the salts in the skin and the metal of the electrode. Removal of the oils and debris decreases the impedance of the electrical contact and increases the effectiveness of the sensor which renders increased sEMG signal amplitude, a decreased baseline noise, and, at times, a reduced line radiation noise.

Liquid electrolyte – Delsys EMG sensors do not normally require an electrolyte to make proper electrical contact with the skin when the skin is cleaned properly. These are referred to as "dry' sensors. They were first introduced by Delsys personnel in 1979 [4]. If the signal quality requires improvement, then a liquid electrolyte should be applied to the surface of the electrodes only. Be very careful not to apply electrolyte on the skin as this would cause an electrical short between the two electrodes and would worsen the signal quality.

Hydrophilic-gel electrolytes – Do not use hydrophilic gel electrolyte if it is likely that a force impulse will be transmitted through the limb to which the senor is attached, as it will enable the occurrence of movement artifact [5]. The viscosity of the hydrophilic-gel causes relative movement of the electrode with respect to the skin, both in the normal (perpendicular) as well as the shear (parallel) direction.

Sensor orientation with fibers – The orientation of the sensor, hence the electrodes, with respect to the direction of the muscle fibers can influence the amplitude of the sEMG signal. The greatest amplitude is obtained when the electrode is perpendicular to the fibers. Also, changing the sensor orientation with respect to the heart will reduce the EKG signal, if one is detected. The sensor is a differential amplifier, thus if both electrodes are arranged so that they are equidistant in the EKG current path the EKG signal will be common mode (similar in amplitude and phase at both electrodes) and it will be removed. If the electrodes are placed along the path of the EKG current, then a differential voltage will be amplified and the EKG signal may be detected.

Location and size of reference electrode – It is advisable to place the reference electrode as far away from the sEMG sensor as is convenient, and not near sources of line radiation such as power cables or lights. Clean the skin with alcohol. Use large (4 to 5 cm) electrodes with strong adhesives that make an effective electrical contact. Placing the reference electrode close to the sensor may disturb the sEMG signal, especially if multiple sensors are attached to the body. An effective reference electrode contact is important. Choose a location that decreases noise interference and prepare the skin accordingly.

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Proximity to heart – When recording sEMG signals from muscles in the chest and upper back it is possible to detect the unwanted EKG signal while detecting the sEMG signal. This interference can be reduced and at times eliminated by using sensors with small inter-electrode spacing and by rotating the alignment of the sensor with respect to the heart.

Reference

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RECOMMENDED PRACTICE
(in order of importance)

1) Use a sensor with a 1 cm inter-electrode spacing.

2) Place sensor in the middle of the muscle surface.

3) Orient the electrodes along the length of the muscle fibers. If using the Delsys sensors, align the arrow along the muscle fibers.

4) Carefully attach sensor to skin.
    a. clean skin with 70% Isopropynol alcohol and
    b. remove excessive hair – in most individuals this is not necessary
    c. use effective adhesive and apply it forcefully
    d. do not use hydrophilic gel electrolyte if movement artifact is a concern

5) Filter signal from 20 to 450 Hz.

6) Use high-quality equipment.

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