



*A Practicum on the Use of sEMG Signals
in Movement Sciences*

Carlo J. De Luca

Curriculum Vitae available at
http://nmrc.bu.edu/fac_staff/director/cv.html

Acknowledgement – Throughout the many years over which this material has been generated, I have had the good fortune of having close collaborations with many wonderful research colleagues and students. They are too many to mention here and some are listed in the cited publications which appear on the slides. Among them, two deserve special mention: Professor Serge H Roy and Mr. L Donald Gilmore. They have made a significant part of this work possible.

A Word on Navigation pane keystrokes scroll through slide index:

Press F6 on the key board to focus on the navigation pane of Adobe. Within each of the tabbed palettes, lists of objects are organized into a tree structure.

Adobe Acrobat 5.0 follows the standard Windows keyboard behaviors for tree views. When the focus is on the navigation pane, the following keystrokes will help you move around:

Ctrl + Tab to access Bookmarks, Thumbnails, Comments, and Signature palettes.

Click on bookmarks to scroll through the page # and title of each slide or sections.



*2: “Electromyography is too easy to use
and
consequently too easy to abuse”*

*De Luca CJ, The Use of Surface Electromyography in Biomechanics,
J. Applied Biomechanics, 13: 135-163, 1997*



3: Guide

Recommendation

Caution

Guide to slide titles:

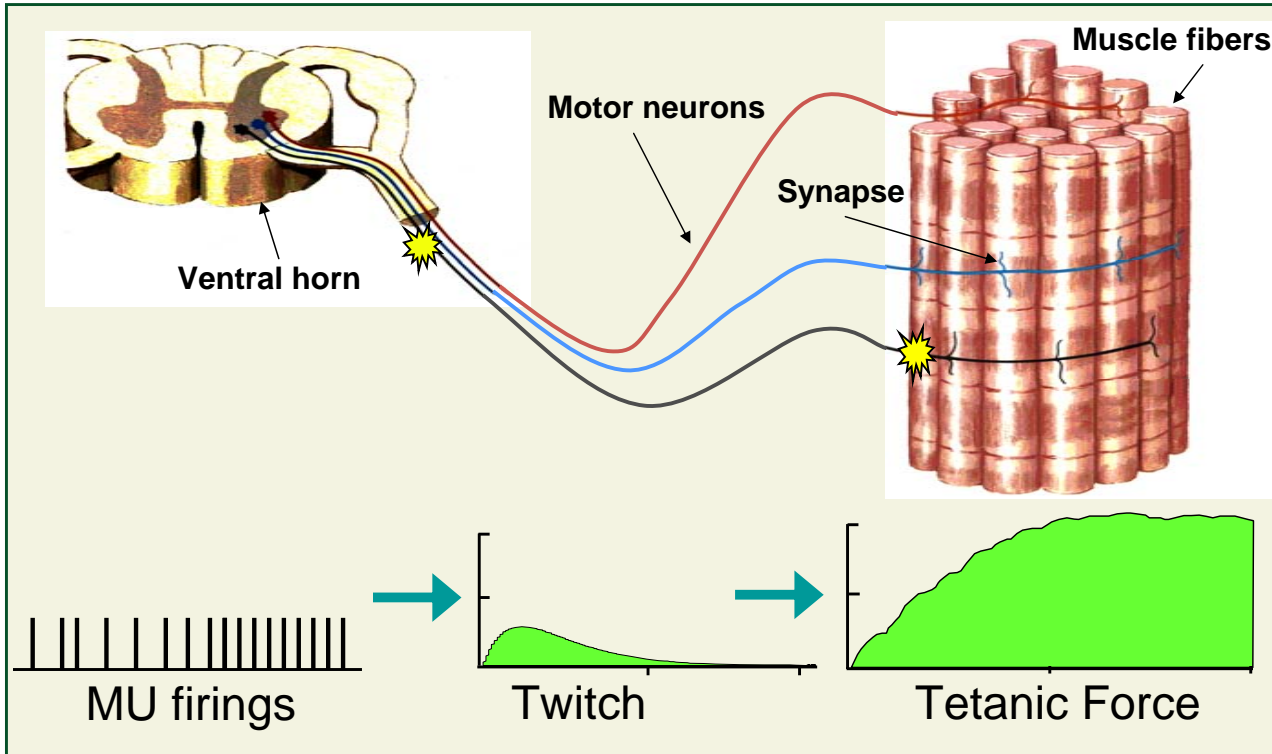
Slides with a heading or title without a border are informational, green ones contain recommendations; whereas those with the color yellow describe conditions and issues that should be handled with caution.



*Section 1:
Basic Concepts Relevant to
Understanding the
Surface EMG Signal*



5: Motor Units and Force



Motor Units and Force:

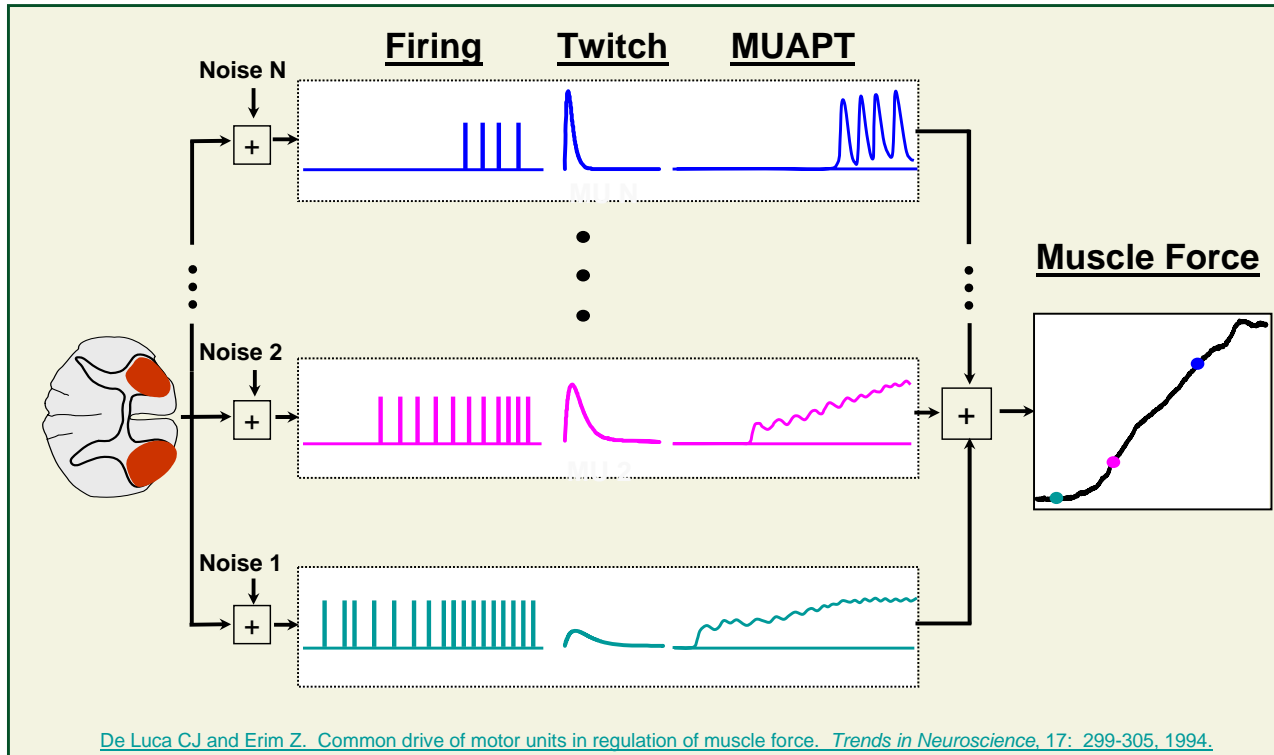
Skeletal muscles are composed of individual muscle fibers that contract when stimulated by a motoneuron. Motoneurons originate in the ventral horn of the spinal cord and consist of a cell body, dendrites (not shown) and an axon. The axon projects to a muscle where it branches, forming synapses with muscle fibers.

A motor unit is the smallest functional subdivision of a muscle. It consists of the motoneuron, its axon and all the muscle fibers that are innervated by its branches. When motor units are activated, the corresponding muscle fibers contract.

Each firing of a motoneuron produces a force twitch in its motor unit. When force twitches occur in close enough succession they superimpose, producing a tetanic (sustained) force. This sustained force is the mechanism which moves our limbs, enables us to breathe, circulates our blood, and enables us to interact with our environment.



6: Motor Unit Control and Force

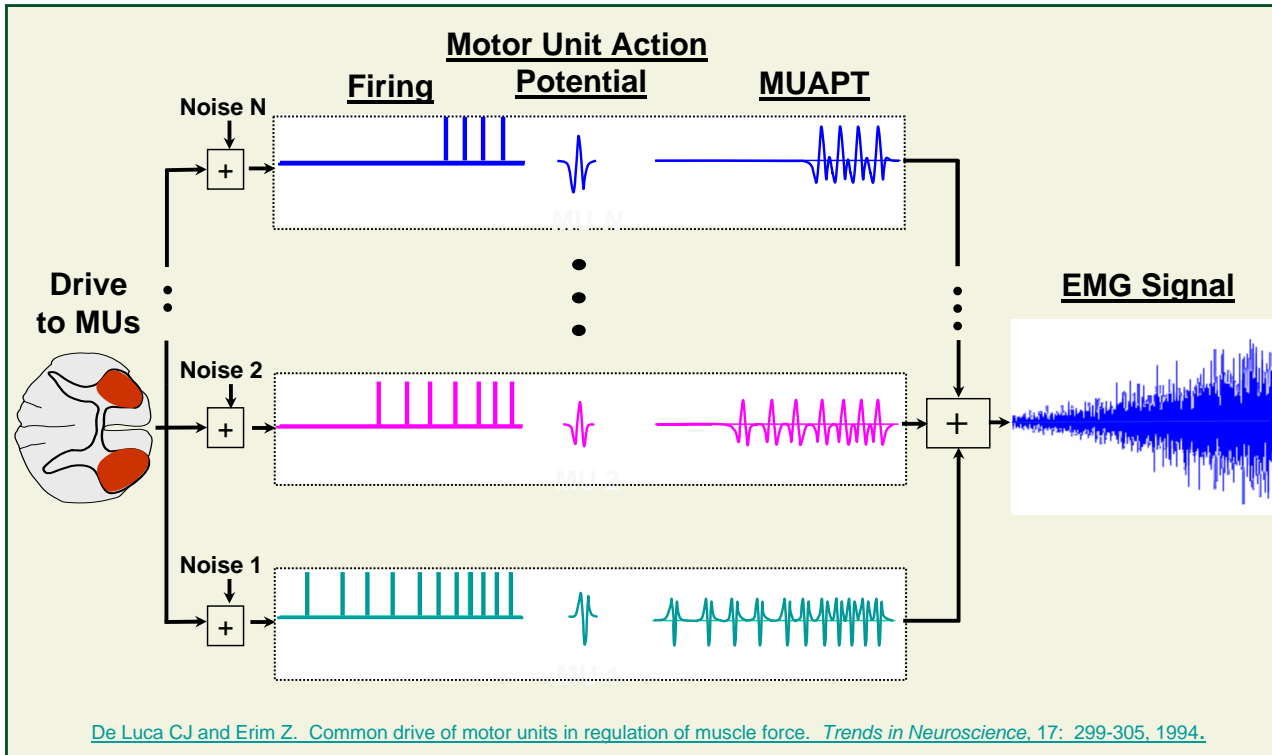


Motor Unit Control and Force:

The force output of the muscle is modulated by the recruitment of motor units and the regulation of their firing rates. The diagram presents physiologically correct concepts that relate the excitation at the anterior horn of the spinal cord to the force output of the muscle. Consider a set of motor units (1, ..., n). Each motor unit is activated by a **Common Drive** (see cited reference) that provides a net excitation to the motoneuron pool in the anterior horn. However, each motoneuron has a noise component (noise N) that consists of background neural activity from the Peripheral Nervous System and from the Central Nervous System. As the excitation increases, motor units are progressively recruited, and all the active motor units simultaneously increase their firing rates (mediated by common drive). In this fashion the earlier recruited motor units have greater firing rates than later recruited motor units. (Note that the firing rate of motor unit #1 is greater than MU #2 and MU #n.). Also note that in the above example the earlier-recruited motor units (slow twitch) tend to tetanize, whereas the later-recruited (fast twitch) motor units do not.



7: Motor Unit Control and EMG Signal



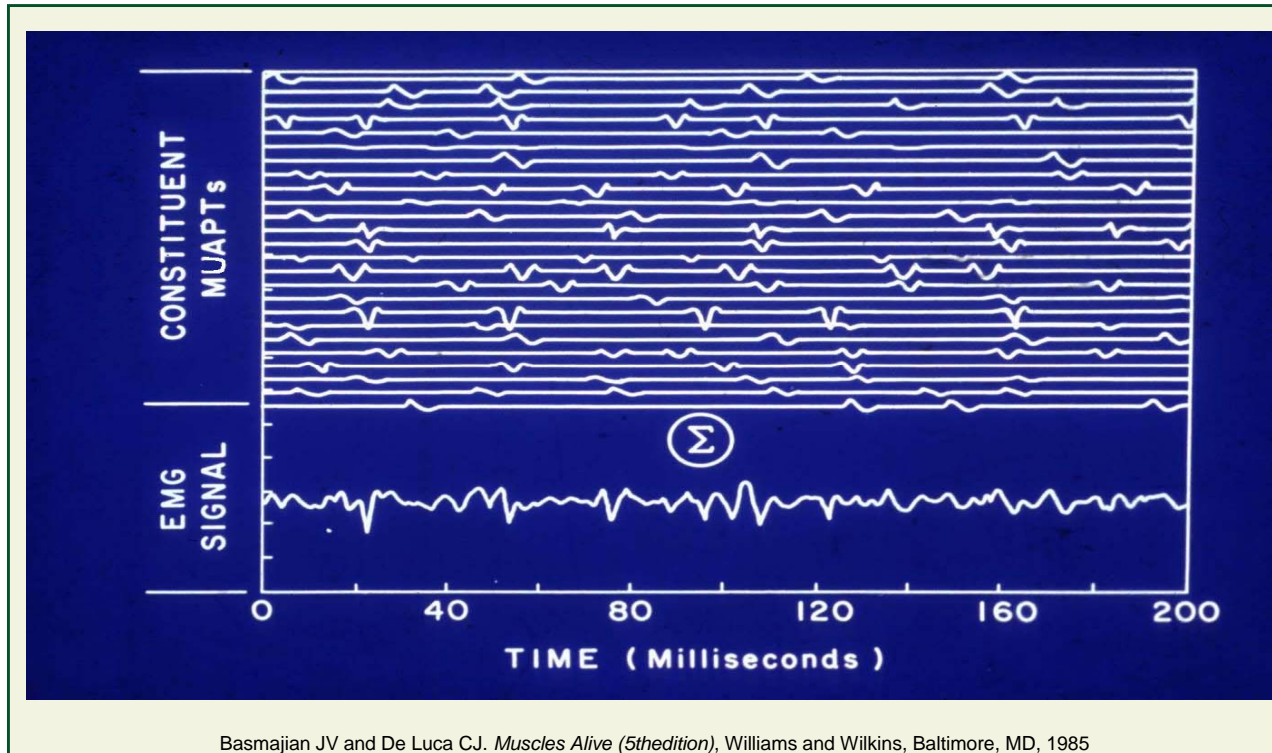
Motor Unit Control and EMG Signal:

This figure demonstrates how the EMG signal is generated while the **Common Drive** (see cited reference) excitation to the anterior horn cell increases. The relationship between recruitment and firing rates is similar to that in the previous companion diagram. Note that as the excitation increases, additional motor units are recruited and the firing rates of all active motor units increases simultaneously. Note that the higher threshold motor units have action potentials of higher amplitude and fire at lower firing rates. Additionally, in sustained contractions at high force levels, the accumulating effects of fatigue may cause the excitation to fluctuate about a set value, then motor units of relatively high amplitudes are sequentially recruited and derecruited causing the variance of the EMG signal (and the force) to increase.

The time sequence of the firings of one motor unit is referred to as a Motor Unit Action Potential Train (**MUAPT**).



8: Synthesized EMG Signal



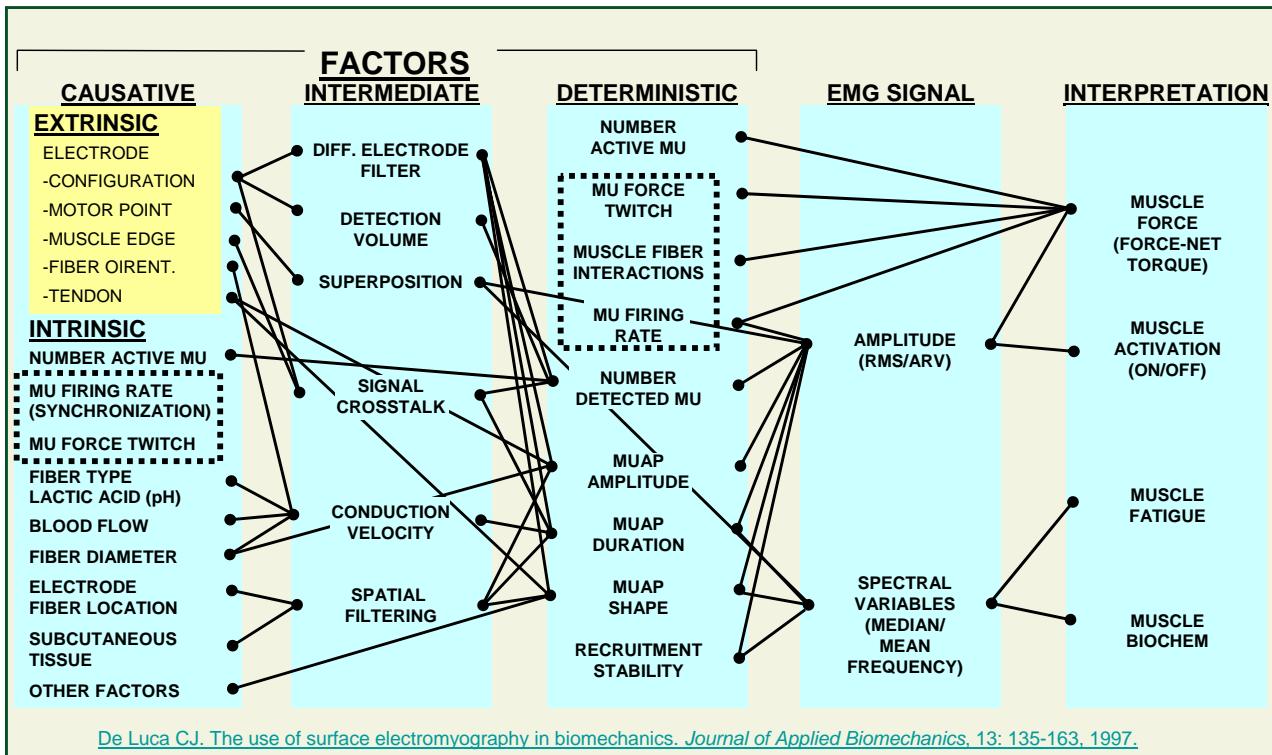
Synthesized sEMG Signal:

An expanded version of the **surface EMG (sEMG)** signal consisting of 25 Motor Unit Action Potential Trains (MUAPT). These are synthesized signals with shapes that closely represent the characteristics of real action potentials. The signal at the bottom is the mathematical sum of all the action potentials which appear in the time sequences above.

The signal at the bottom is what the sensor sees and the roster above it is the code sent by the CNS that is seen by the muscle fibers. The purpose of EMG signal decomposition is to find, from the signal recorded by the sensor, individual MUAPTs. Being able to do this allows a closer investigation of the control mechanisms governing motor activity.



9: Factors that Influence the EMG Signal



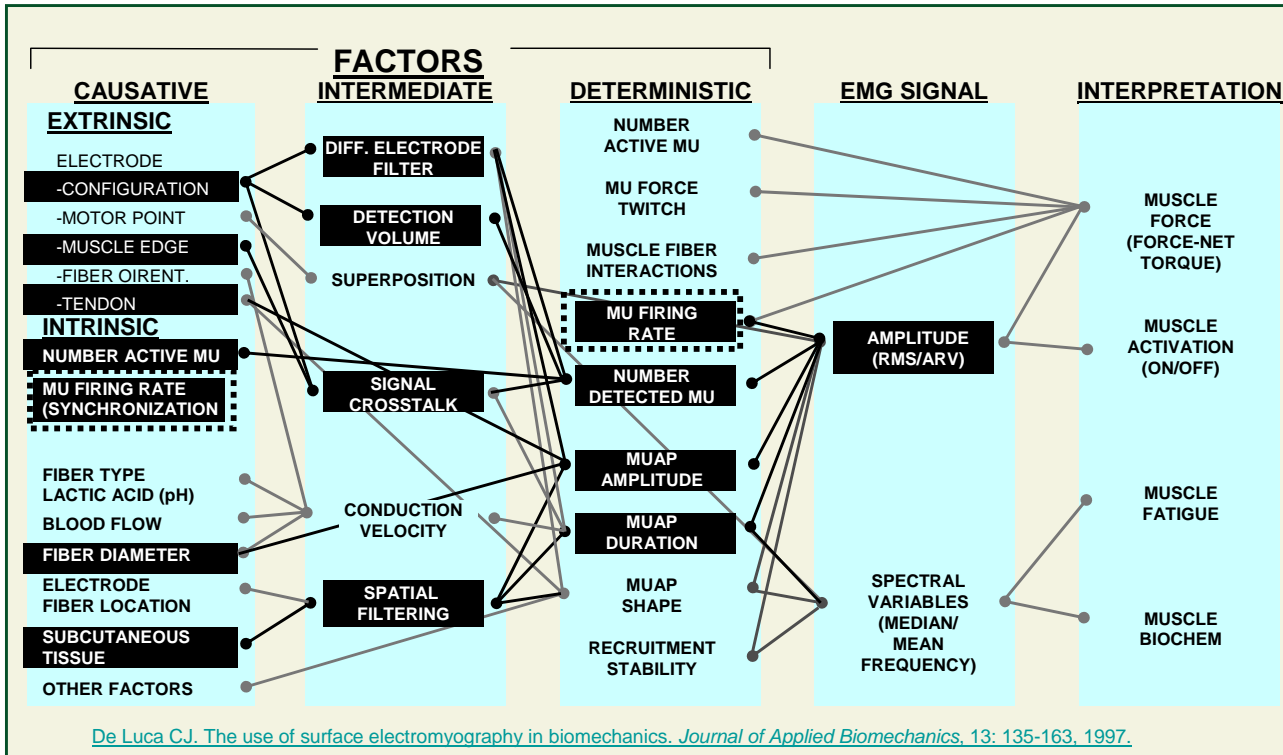
Factors that Influence the EMG Signal:

Schematic diagram of the factors that affect the EMG signal. The arrangement of factors is designed to demonstrate the flow of influences and interactions among the factors, as well as the complexity of their interaction. The section highlighted in yellow (the extrinsic factors) refers to the sensor design and the manner used to attach the sensor on the skin. These are factors that can be controlled by the sensor manufacturer and sensor user. **How and where** one locates the sensor on the skin above the muscle has **dramatic** effect on the signal quality. This topic will be discussed in greater detail in Chapter 3. The intrinsic factors as well as the remaining groups of factors refer to anatomical, physiological, and electrical properties that are not controllable by the user, but must be taken into account when interpreting sEMG results.

For additional details explaining the remainder of the diagram please refer to the cited reference.



10: EMG Signal Amplitude at $t = 0^+$



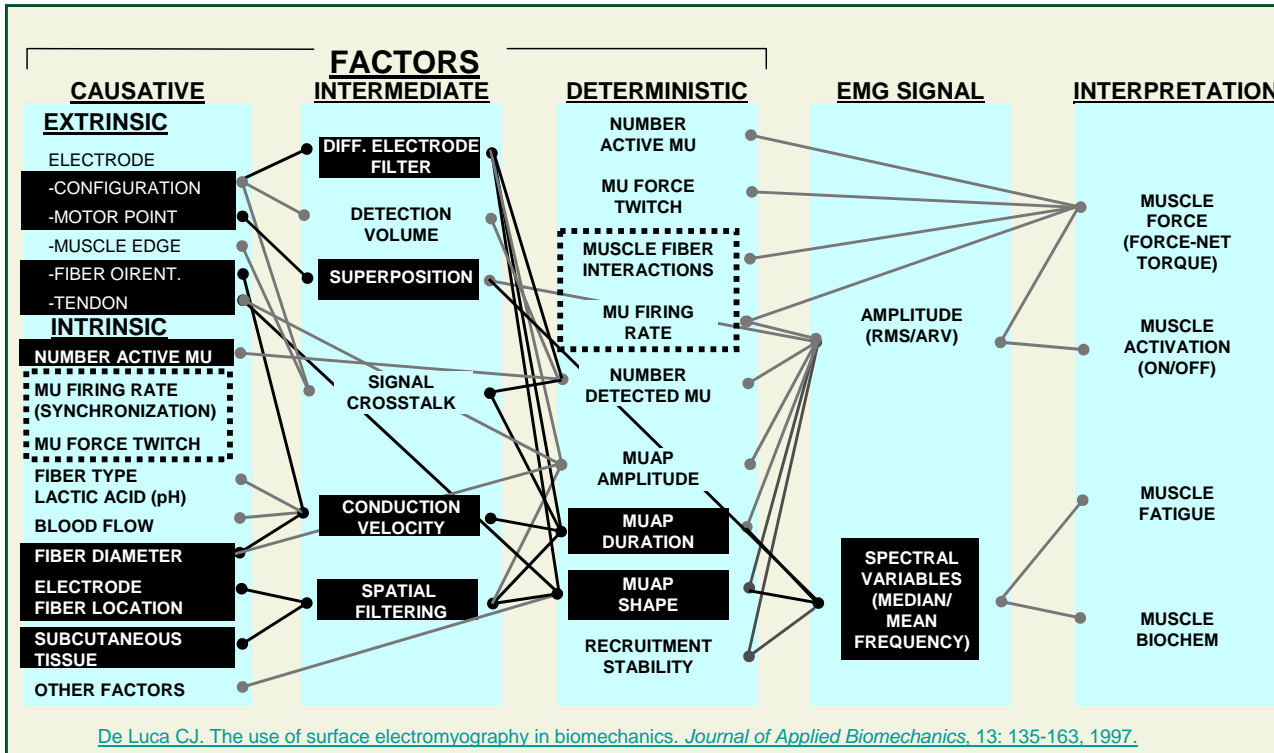
EMG Signal Amplitude at $t=0^+$:

The segments highlighted in black show the interrelationship of factors affecting the EMG signal amplitude at the beginning of a contraction ($t=0^+$), that is when no fatigue is present. Factors which are active at this stage of contraction are shown. The time-dependent (fatigue influencing) factors that would be influential during a sustained contraction are not shown.

For further explanation about the remainder of the diagram please refer to the cited reference.



11: Spectral Variable at $t = 0^+$



Spectral Variable at $t=0^+$:

Factors that influence the frequency spectrum of the sEMG signal at the beginning of a contraction ($t=0^+$), when the influence of fatigue is not present, are shown highlighted in black.

For more on muscle fatigue, skip to slide 87.



12: Why Use the sEMG Signal?

As complex as it may appear from the previous slides, the sEMG signal can be used in the following applications

Note that some applications are limited to isometric contractions and/or constant-force contractions

A) Obtain parameters from individual or groups of muscles

- Force (isometric contractions)
- Activation Time (ON – OFF)
- Fatigue (constant-force, isometric)

B) Compare behavior of different muscles

- Relative amount of contribution
- Co-activation
- Pattern identification (tasks)

Why Use the sEMG Signal?:

From the perspective of Movement Science, these are the main applications of the sEMG signal:

Muscles produce force. Biomechanical studies often require us to know the force contribution of individual muscles. Mechanical instrumentation which records this data is complicated and almost always invasive. Under proper conditions the sEMG signal detected from **individual** muscles can provide this information.

The relationship between the sEMG signal and force is valid only for isometric contractions (those for which the muscle length remains constant). sEMG fatigue parameters calculated with Fourier transforms are valid only for constant-force, isometric contractions.

The detected sEMG signal **must** contain the least amount of contamination from adjacent muscles, otherwise the **individuality** or **relativity** of the information in the sEMG signal is not maintained. The relationship between force and the sEMG signal is also used for biofeedback and for controlling external electro-mechanical devices such as prosthesis, robots, and household appliances.

The timing of activation and contraction between different muscles is often a useful parameter that can be obtained from the sEMG signal. The activation timing can be used to address issues concerning the fine tuning of muscle use in skilled performance or for assessing the discordant activation in neurologically impaired patients.

As a muscle contraction is sustained the chemical activity within the muscle alters some parameters of the sEMG signal. The non-invasive and real-time nature of the assessment of these parameters makes the signal useful in some applications in ergonomics and clinical assessments.