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PERFORM Operating Document

TeleMyo Direct Transmission System (DTS)

PC-POD-FA-001-v03

Revision History

Version	Reason for Revision	Date
03	Scheduled Revision and Update. Added DTS Footswitch and Analog Input Sensor Information.	Jul/6/2020

1. Overview

The content of this PERFORM Operating Document (POD) provides guidelines for:

- Operation of the TeleMyo DTS hardware
- Skin preparation and hardware placement
- Use of TeleMyo DTS with VICON Motion Capture
- Use of MyoResearch XP Master Edition software

2. Definition of Terms and Abbreviations

Ant.	Anterior
Abd.	Abdominis
I.	Inferior
M.	Middle
S.	Superior
.csv	Comma-Separated Values file type
.txt	Text file type
DSSS	Direct-Sequence Spread Spectrum
sEMG	Surface EMG
FSR	Footswitch Resistor
SENIAM	Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles
RMS	Root Mean Square
V	Volts

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3. Introduction

The TeleMyo™ Direct Transmission System (DTS) directly transmits data from the electrode or sensor site to the receiver. This direct transmission concept greatly simplifies the arrangement of measurements by eliminating the need to arrange cable connections. The small, light-weight probes are also beneficial for small participants such as children and older adults. The Belt Receiver can operate in 3 modes:

1. Direct connection to any PC via USB connection (transmission range 10m)

2. Wireless retransmission of signals in real time to any Noraxon USB receiver (transmission range up to 100m)

3. Data logging via Flash Memory card

These features give flexibility in operating the DTS system without physical limitations. The compatibility to Noraxon's USB receiver systems, operated via WiFi based retransmission of data, allows you to integrate up to 8 additional stationary analog input signals and optional analog output of all signals (i.e. connect signals to the VICON motion capture system).

The current DTS system operates up to 16 channels. The Functional Assessment Suite has 16 electromyography (EMG), two footswitch, and one 5V universal analog input sensors available to be integrated into the DTS system. These sensors can be used on their own or in combination with one another.

As a user, you must first decide if you will be using the DTS system on its own, or in conjunction with other equipment. The system is synchronized with the Vicon motion capture system but can be synchronized with other Functional Assessment devices.

This document will cover the setup of the TeleMyo DTS system with EMG, footswitches, and universal analog input sensors, and the setup for the system in conjunction with the Vicon system.

3.1 TeleMyo DTS Specifications

Power Requirements
• Replaceable Li-ion rechargeable battery, operation time more than 8 hours after fully charged

Belt Receiver Output & Transmission Frequency (Depending on country)
• Up to 100 mW (depending on antenna and country allowance)
• WiFi DSSS 2412-2464 MHz on (up to) 11 selectable radio channels
• Belt Receiver Re-Transmission range: up to 100 meters in line-of-sight recordings

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DTS Sensor Output & Transmission Frequency
• Transmission range: 10m
• Output power: 4mW
• Footswitch Output Signal Range: 0 – 5V
• DSSS 2400-2472 MHz on 5 selectable radio channels

DTS Sensor Data Acquisition System
• 16-bit resolution
• 1500 Hz sample rate (for 16-channels)
• Selectable low pass filter 500, 1000, 1500 Hz

DTS Sensor Preamplifiers
• No notch (50/60 Hz) filters are used
• 1st order high-pass filters set to 10 Hz +/-10% cutoff
• Baseline noise: < 1 uV RMS
• Input impedance: > 100 Mohm
• CMR: > 100 dB
• EMG Sensor input range: +/- 3.5 mV
• Universal Analog Input Sensor input range: +/- 10 V
• Base gain: 400
• Pinch-style terminal electrode connections for EMG
• Rechargeable Lithium Polymer battery

Dimensions
• EMG Sensor Dimensions: 3.4 cm L x 2.4 cm W x 1.4 cm H
• EMG Sensor Weight: Less than 14 g
• Footswitch Sensor Dimensions: 3.4 cm L x 2.4 cm W x 1.4 cm H
• Footswitch Sensor Weight: 17 g
• FSR Sensor Diameter: 18.5 mm
• Footswitch Sensor with Cable Weight: 28.3 g
• Detachable Sensor Lead Length: 31 cm
• Universal Analog Input Sensor Dimensions: 3.4 cm L x 2.4 cm W x 1.4 cm H
• Universal Analog Input Sensor Weight: 18 g
• DTS Belt Receiver Dimensions: 12.6 cm L x 6.75 cm W x 2.38 cm H
• DTS Belt Receiver Weight: Less than 185 g

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3.2 Equipment Photos

3.2.1 Belt Receiver
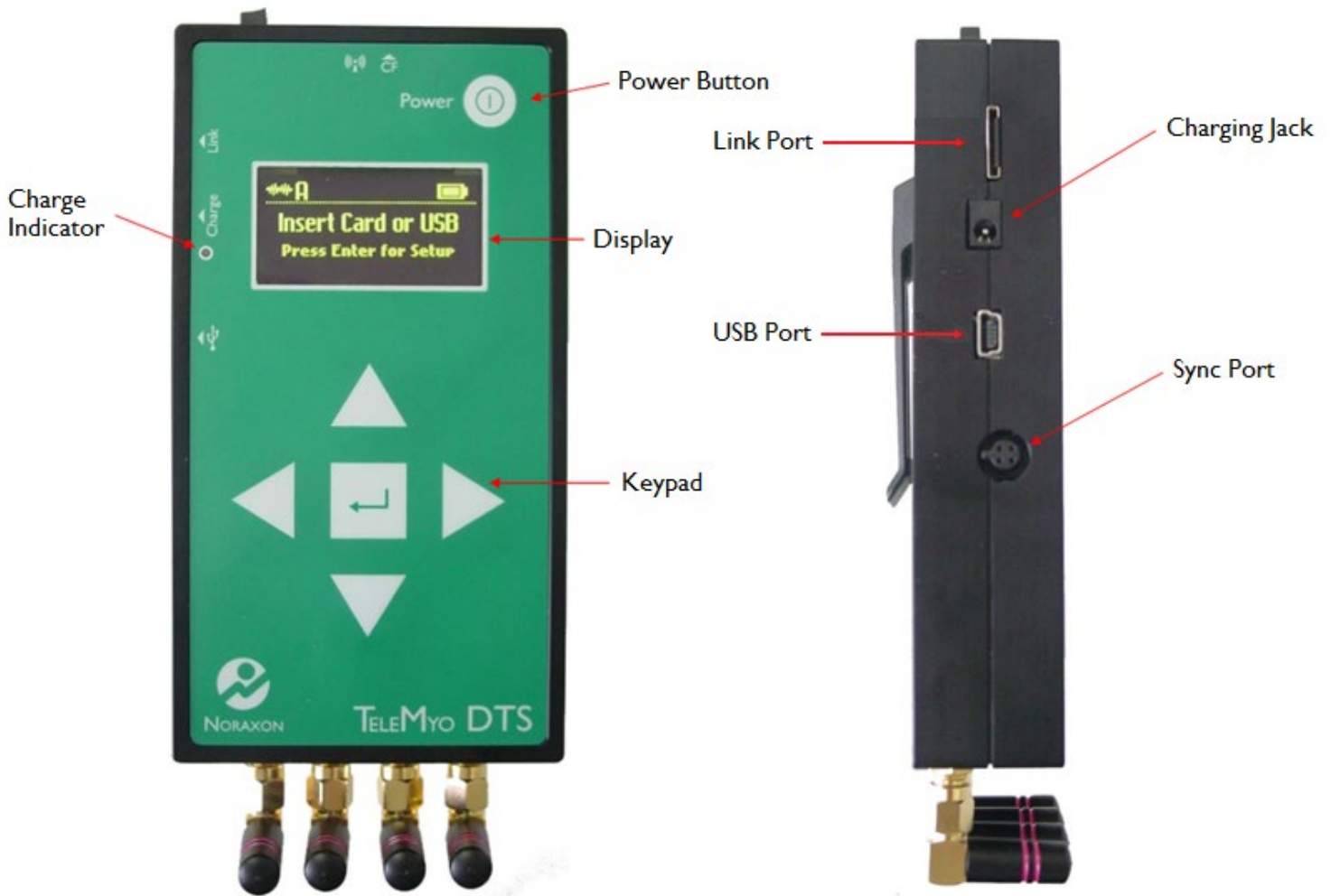
Front   Side

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3.2.2 EMG Sensor

Front

Status LED

Charge LED

Top/Back

Lead Connector

Reference Electrode
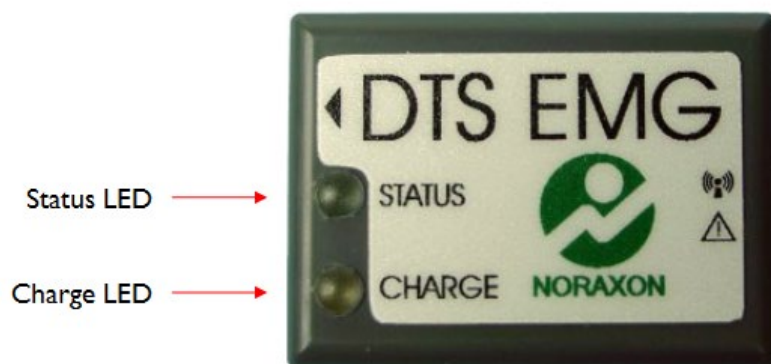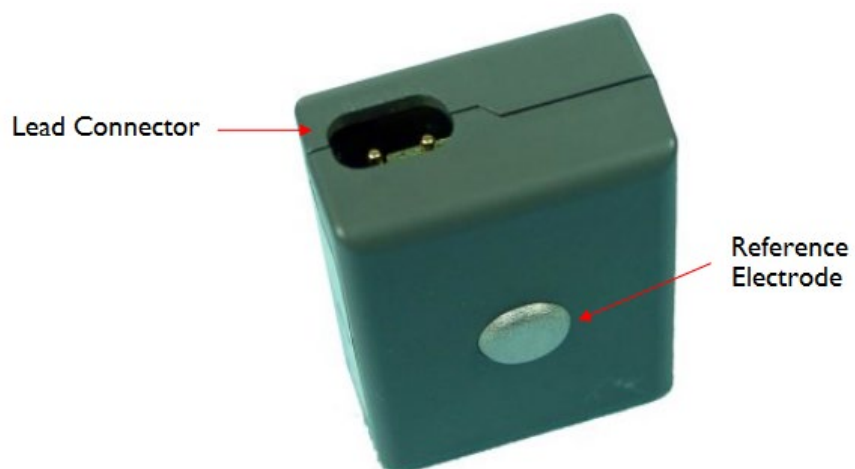
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3.2.3 Footswitch Sensor

3.2.4 Universal Analog Input Sensor

4. Procedure

Whether the device will be used with the Noraxon data collection package or with the Vicon system, the basic principles regarding the use of the device are the same. Outlined in this section are instructions on operating the DTS system with the available sensors at PERFORM.

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4.1 Training

All users must read and sign this POD to receive the proper training in applications and instrumentation. Users should never modify the equipment.

4.2 General Operation

The DTS sensors require minimal attention on the part of the user. Because there are multiple DTS sensors, each sensor has a unique 4 character serial number consisting of a mix of digits 0-9 and letters A through F, which provides a simplified means of identifying one sensor from another. This serial number appears on each DTS sensors (adjacent to its charging contacts).

The sensor's green STATUS indicator provides a means of communicating its operational state. In the idle state the STATUS indicator will flash at a low, once per second rate. When the sensor is actively measuring a signal the STATUS indicator will flash recognizably faster. If the STATUS indicator is not flashing at all, the DTS sensor must be placed in the charging dock to be recharged. This could be due to a depleted sensor battery or if the sensor was deliberately shut down. The Charge LED on an DTS sensor is solid orange when charging in the charging dock. The solid orange LED of an DTS sensor will turn off when it is fully charged.

4.3 EMG Operation

For proper operation for EMG, the DTS sensor must be applied to the measurement site so that the adhesive side of the disposable electrode is in direct contact with bare skin. Skin preparation for the reference pad site may be beneficial if the EMG signal exhibits a wandering baseline. The EMG sensor can be secured in place using Noraxon supplied double sided adhesive tape, medical tape and/or elastic straps. Straps are recommended if very dynamic movements are expected.

The EMG sensor allows for interchangeable terminal lead wires for attachment to disposable electrodes. The two lead wires are offset with one longer than the other by an amount equal to the standard 2 cm spacing for surface EMG electrodes. The 2-pin lead wire connector can be inserted either way into the EMG sensor to facilitate attachment to the surface electrodes. There are 2 lead lengths currently available: 10 cm and 15 cm leads.

4.3.1 Skin Preparation

In order to ensure proper signal transmission, the surface of the skin under the electrode and under the transmitter must be cleaned and cleared of debris. This will ensure proper contact and signal transmission.

4.3.2 Removal of Hair

If the participant has hair where the electrodes will be placed, this must be shaved without the use of shaving cream, which leaves a film and impedes electrode adhesion and electrical conduction.

4.3.3 Cleaning of Skin

The skin under the electrode must also be cleaned. This can be done using a special abrasive conductive cleaning paste, but the use of an alcohol and a gauze pad is sufficient. The skin must be cleaned and abraded enough to remove a layer of skin. Temporary redness of the area that was cleaned is a sign that the skin area has been sufficiently cleaned for EMG.

4.3.4 Surface Electrode Placement

Once the site has been properly prepared and dried, the electrode and DTS sensor can be placed. Here are a few guidelines for electrode placements:
1. Wet-gel electrodes have the best skin impedance values
2. Use small electrodes to increase the selectivity of your measures (avoid cross-talk)
3. The recommendation for the inter-electrode distance is 2 cm
4. Apply electrodes in series to the muscle fiber direction
5. Use the dominant middle portion of the muscle belly for best selectivity
6. Take care that the electrode site remains on the active muscle mass during muscle shortening (i.e. biceps brachii)
7. Use a map system with measured distances between the electrode site and dominant anatomical landmarks (Fig. 4.3-1 and 4.3-2)
8. Ensure participant does not sit on or apply too much pressure to the electrode or transmitter

Knowledge of muscle origin and insertion is also important. For the standardized electrode placement of the most common muscles recorded using sEMG, visit the SENIAM Project (http://www.seniam.org/). Click the header 'Recommendations' -> 'Sensor Locations' and follow the links for each of the regions of the body and the muscles that comprise them.

4.3.5 Securing the Cables

Finally, securing the electrodes and sensors on the skin is sometimes necessary. This point may be not as important for static or slow-motion tests, but in dynamic studies it helps to avoid cable movement artifacts and minimizes the risk of separating the electrodes from the skin. Use medical tape, elastic straps or net bandages to secure each electrode lead, however, caution against too much tension around the electrode site. It is recommended not to directly tape over the electrodes to keep a constant application pressure for all electrodes and thus reduce unwanted noise in recorded signals.
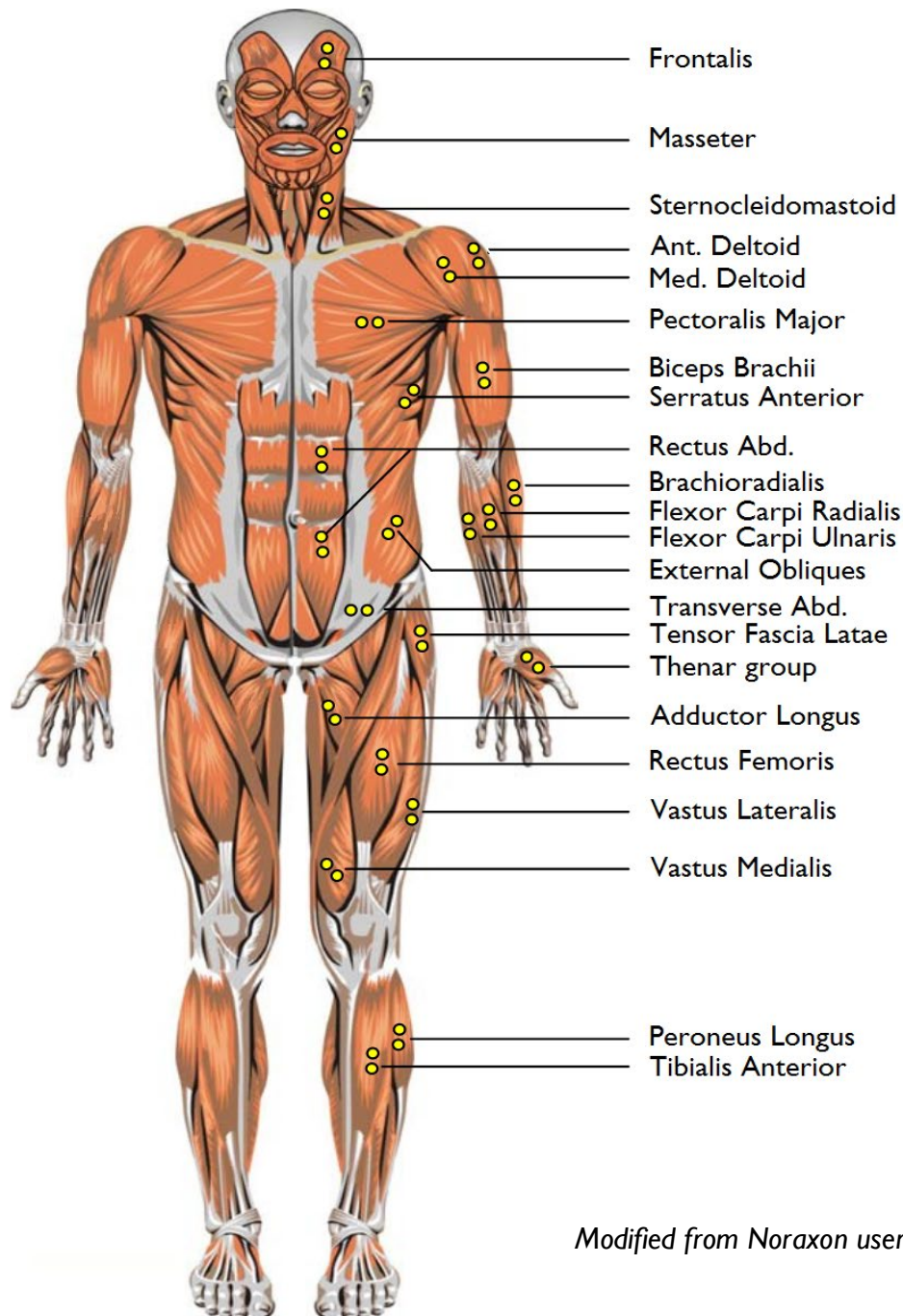
4.3.6 EMG Signal Validity

This checkpoint addresses the basic questions: "Did I measure the right muscle?" and "Can I see valid signals?" There is a possibility of accidentally applying the wrong cable end to the muscle (i.e. the wire designated for one muscle is mixed with another). Checking all connections again can confirm the EMG signal by a specific muscle function test for that particular muscle (i.e. elbow flexion to test biceps brachii). Detection sites over very thick subcutaneous fat tissue (e.g. more than 4 cm) may mean that no EMG signal is visible at all or the EMG to baseline ratio is poor. Explicit / isolated contraction

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muscle testing gives you a clear understanding of whether the EMG recording will reveal valid data and/or if the participant is able to activate the muscle.

The following figures illustrate the muscle maps of muscles that are typical sites in studies. The two yellow dots on the surface of the muscles indicate the orientation of the electrode pair in relation to the muscle fiber direction.

4.3-1 Frontal Muscle Map:

Frontalis
Masseter
Sternocleidomastoid
Ant. Deltoid
Med. Deltoid
Pectoralis Major
Biceps Brachii
Serratus Anterior
Rectus Abd.
Brachioradialis
Flexor Carpi Radialis
Flexor Carpi Ulnaris
External Obliques
Transverse Abd.
Tensor Fascia Latae
Thenar group
Adductor Longus
Rectus Femoris
Vastus Lateralis
Vastus Medialis
Peroneus Longus
Tibialis Anterior

Modified from Noraxon user manual

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4.3-2 Dorsal Muscle Map:

Splenius Capitis

S. Trapezius

M. Trapezius
Posterior Deltoid
Infraspinatus

I. Trapezius
Triceps Brachii (long & lat. heads)
Lattissimus Dorsi

Erector Spinae Longissimus
Erector Spinae Iliocostalis
Extensor Carpi Ulnaris

Gluteus Medius
Gluteus Maximus

Biceps Femoris
Semitendinosus

Gastocnemius (med. & lat. heads)

Soleus
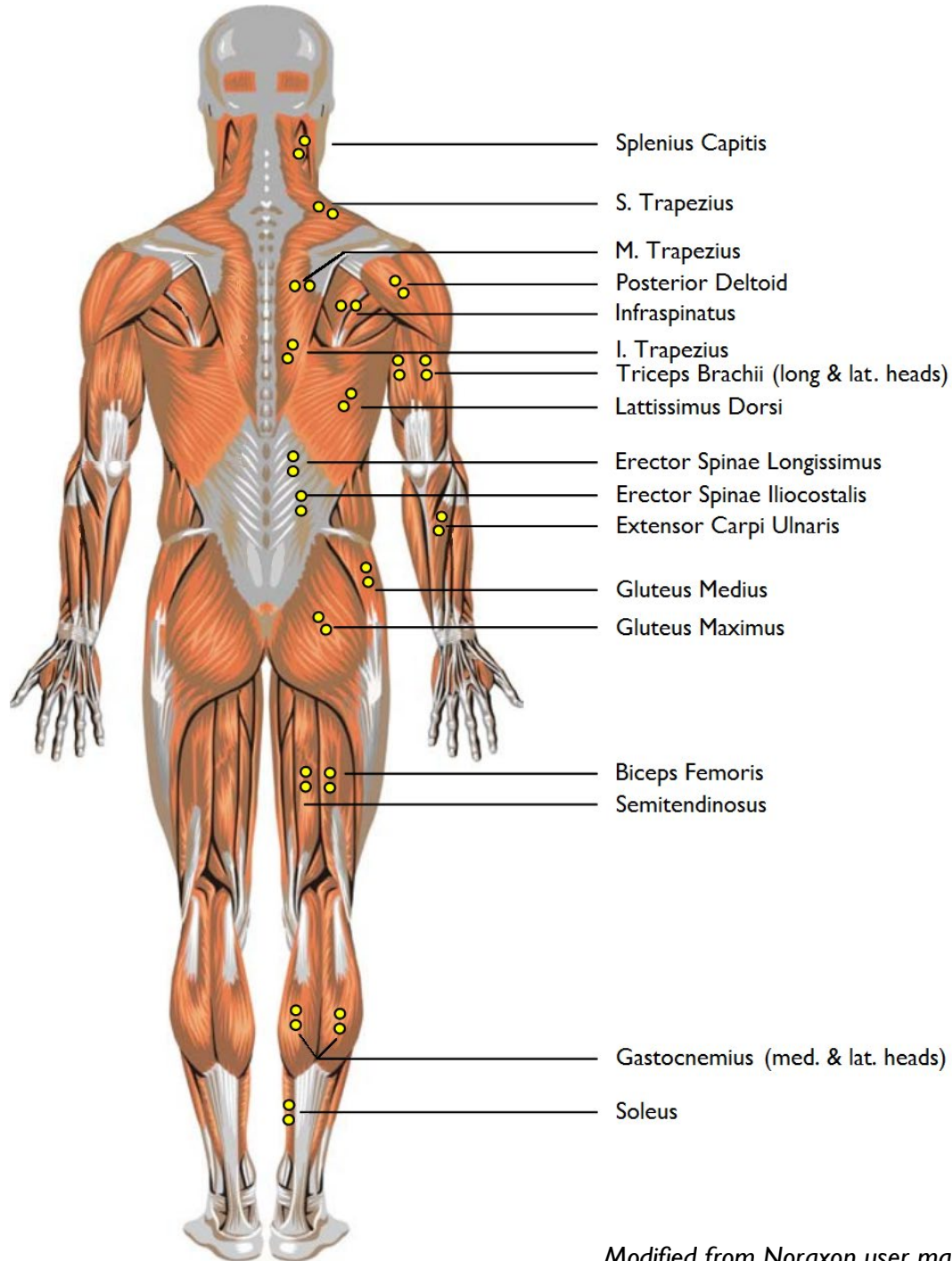
Modified from Noraxon user manual

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4.4 Footswitch Operation

For proper operation for footswitches, the DTS sensor should be placed on the ankle. To minimize the risk of tripping, the lead wires should be fixed around the ankle with medical tape. The footswitch resistor (FSR) sensor must be placed with the resistor surface (gold colour) facing out in the location designated on the label around each lead wire. The location abbreviations are defined as follows:

- T - 1st toe
- H – Heel
- 1 – 1st metatarsal
- 5 – 5th metatarsal

The maximum footswitch capability setup is shown below:

While four FSR sensing areas are available, the footswitches may be used with one to four FSR sensing areas.

Modified from Noraxon user manual

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4.4.1 Footswitch Signal Validity

To check that the footswitches are transmitting a valid signal, gently tap on each FSR sensor and see if a signal response occurs and appears in the software. Each location will generate a unqiue voltage as follows:

- No pressure - 0 V

- Heel - 0.267 V

- 5th metatarsal - 0.533 V

- 1st metatarsal – 1.067 V

- Toe – 2.133 V

- All – 4.0 V

After each FSR sensor has been checked, have the particpant walk a few steps to test if the signals transmit properly during walking. If the signals do not consistently transmit, readjust the placement of the FSR sensors on the foot.

The signal generated by each FSR is an "all or nothing" response. For example, the heel area will only generate a signal of 0.267 V when activated. A gradual build-up to the active voltage does not exist. The signals of the FSRs can be cumulative and produce values that are not any of those listed above. An example signal where all four FSR sensors on one foot are active is shown below:

4.5 Universal Analog Input Operation

The DTS universal analog input sensor can be used to mark events and sync multiple systems where integration with each other is not possible. The analog input sensor takes in a voltage signal from a source within +/- 5V and transmits a signal representing the input voltage, which can be used to identify events and align the data streams from the different systems.

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4.5.1 Universal Analog Input Signal Validity

Test signals from the source should be sent to the analog input sensor to verify the source voltage signal is being received and properly transmitted. Unlike footswitch signals, analog input signals may not exhibit an "all or nothing" pattern and signal magnitudes will vary depending on the source.

5. Data Acquisition

5.1 Vicon Nexus

Once the acquisition computer is turned on, double-click the Vicon Nexus icon. Ensure the Vicon Giganet pre-amplifier is turned on, that the proper system configuration is chosen, and that the database being written to is correct.

Plug in the TeleMyo DTS receiver to the computer via USB. Ensure there are no internet browsers open at the same time as there is an issue with the acquisition computer being connected to the internet while trying to collect data. It appears to interfere with the TeleMyo receiver and it desynchronizes the DTS sensors. Turn on the TeleMyo DTS receiver. It is properly interfacing with the computer when you hear a chime. In Nexus, click on the *System* tab on the left-hand side of the window and select *#1 (Noraxon TeleMyo)* in *Devices*. Click *#1 (Noraxon TeleMyo)* and in the *Properties* pane underneath, change the number of DTS channels from 16 to 8, wait for the device to synchronize, and then revert to 16 channels. *N.B. This is a Vicon/Noraxon patch issue that does not allow the DTS system synchronize without doing this*. With the 16 channels selected right-click the voltage tab and add in each individual channel, one by one, making sure it synchronizes until the desired number of channels is reached. A status window will briefly appear each time a channel is successfully added. Once the desired number of channels are added, right-click on *Local Vicon System* and then click *Resynchronize*. Highlight the DTS channels and select *Graph* in the central viewing window in Nexus. The live DTS sensor traces will show up if the device has been properly synchronized.

5.2 XP Master Edition

5.2.1 Main Screen Elements

Project is the highest level in the hierarchy of the MyoResearch XP Database. This level can be used to separate different projects or users working in the same version. For several projects available in one version, you can click the pull-down button to open a list of all existing projects and change to another *Project Directory*.

If you are creating a new project, in the *Project* section in the top left corner, click *New*. A dialogue box will open, where you can enter the name of the project. Once you have entered the name of your project in the text box, click *OK*.

Organize contains all operations needed to manage a Project Directory (Edit, Copy, Delete). *Subjects* are the second level in the MyoResearch XP Database System. Typically, all records (third level) of one subject are stored and listed here. To add a new subject, click *New* in the *Subject* section. A dialogue box will open where you can input subject information. Once all the necessary information has been filled out, click *OK*.

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To begin recording, click on *Measure* on the bottom left corner of the window, which will bring you to the *Measurement Setup*.

5.2.2 Measurement Setup Screen Elements

There are a few different panes in *Measurement Setup* which are important, namely *Muscle/Device Maps*, *Channels* and *Application/Configuration*.

The left pane is the *Muscle/Device Maps* where you can review the recommended EMG placement sites for muscles and add sensors to set the collection configuration that will be used.

In the *Channels* pane, the user can select which channel they desire to record, which side of the body they are recording, the name of the channel (which also changes depending on selection), the type of recording (default is EMG), the signal amplitude (default is 500), the units (default is μV) and whether or not this channel will be recorded (default is set to record). These options are all setup by default to record EMG but if other sensors are part of the collection configuration being used, the information would be changed in this pane.

On the right pane there are the *Application*, *Configuration* and *Measurement Options*. The *Application* window displays the icons representing the *Application Group* that is currently active. *Measurement Configurations* are sorted by their applications, e.g. gait configurations are in *Gait* and clinical feedback protocols in *Feedback Training*. This grouping helps you sort and manage the numerous *Measurement Configurations*. MyoResearch XP is equipped with a set of predefined *Application Groups* that cover a wide range of signal processing applications. You may want to use, modify or create your own *Application Groups* and *Measurement Configurations*.

The *Measurement Options* window contains various options which can be customized for your collection, such as acoustic beeper, real time processing, biofeedback displays and synchronized video. For in depth information on all these options, refer to pages 38-45 in the MyoResearch XP Master Edition User Manual.

5.2.3 Recording Trials

Once you have selected the desired recording channels and have configured the data collection trial to suit your needs, click on the *Start* button at the bottom left of the window. This will bring you to the *Measurement Monitor* where a live trace of the channel will be displayed. Before recording, ensure that the baseline of the trace has been zeroed by clicking *Zero Offset*. You can also add manual event lines or time stamps by clicking *Mark* during the recording trials. Once you have finished your recording, click *Stop*.

After completing a data acquisition trial, click *Database* to return to the *Subject Database* menu. From here, you can highlight the newly acquired data and begin processing.

5.2.4 EMG Signal Processing

From the *Subject Database* window, highlight any of the trials to process and click *View/Analyze*. A signal trace will appear in the *Signal* window, as well as any events that were entered using the *Mark* function during acquisition. In the centre pane is the *Bar*

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Graph where discrete samples of an EMG signal can be displayed in a bar graph. Both these displays can be used to manually inspect elements of an EMG signal.

On the right hand side in the *Record* option, you can begin processing recorded EMG signals. Clicking the *Marker Menu* brings up various options for manually adding markers, automatically adding markers by threshold, max/min, etc. The main purpose of setting markers is to define analysis periods of your trace. For specific details on marker options, refer to pages 82 – 85 of the MyoResearch XP Master Edition Manual.

Next is the *Edit* menu. *N.B. Any changes made to the EMG signal are permanent; it is recommended that a copy be made for backup before editing the signal.* Alternatively, save any changes done in *Edit* mode with the *Save As* option which allows the creation of a new record file (including all changes) but keeping the source record in its original status. The edit operations are organized in two *Tools* sections: *Channel* and *File Tools*. All *Channel* tools can be applied to each individual channel, whereas *File Tools* affects all channels. For a complete list of tool functionality, refer to pages 86 – 91 of the MyoResearch XP Master Edition Manual.

The next button in the *Record* option is the *Signal Processing* tool. This is where the raw signal is manipulated to obtain outcome measures. Typically, raw EMG data is processed by several signal processing methods such as rectification, smoothing and normalization before an analysis is started (exception: frequency-based analysis types). Any signal can be restored to its original raw status.

Five signal processing methods, listed under *Available Operations*, can be loaded in a sequence of *Selected Operations*. You can create any sequence and order of processing methods and load them several times if needed. *N.B. The order in which you insert the Available Operations is the order the operations will be run on trial data.*

5.2.5 Available Operations

Rectification: This very popular processing method takes the absolute value of all amplitude values, making all negative values positive. The reason for this operation is to achieve positive amplitude curves that allow the user to calculate outcome measures such as mean amplitude, area under the curve, etc.

Smoothing: Typically, for amplitude-based calculations and analysis, the raw signal is smoothed by digital filters, root mean square or moving average algorithms. The result is non-reproducible signal spikes are eliminated and the mean trend of the signal is preserved.

The following smoothing algorithms are supported:

- **RMS**: Root Mean Square
- **Mean**: the moving average
- **Mean Absolute**: the moving average combined with rectification

Window: allows the user to define the millisecond-based window for each algorithm

Amplitude Normalization: 5 normalization routines are available in the pull-down list:

- **Manual Value**: normalize based on a manually-entered value; different values can be applied to different channels
- **Peak Value**: This is the main method of finding MVC (Maximum Voluntary Contraction) values within MVC records. The entry window defines a window

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for the MVC value calculation. The mean value of this window is taken as the MVC value. An automatic algorithm calculates each selected channel separately where the highest mean window of the signal is indicated with a green color. When done, a prompt appears that asks you to *Update the MVC Stack*. The *MVC Stack* is an internal memory that keeps these MVC values if it is filled by the next *Peak Value* normalization operation. When confirmed by clicking *Yes*, these MVC values are available for the *MVC Stack* normalization routine. The functions *Restrict calculation to...* and *Pick* can be used to mark a signal portion in the collected data, with the result being that MVC calculations are only performed in this marked area. This function may be helpful in measurement designs where an MVC recording period is a subset of a given trial.

- **To Mean Value**: In this normalization method, the amplitude mean value is calculated for each channel and taken as a reference value for normalization. This type of normalization is often used in gait analysis where time normalized EMG signals are amplitude normalized again to its own mean value.

- **MVC Stack**: This method loads the current MVC values from the stack. This can be repeated as many times as needed. The MVC values remain in the stack even if the computer is shut down. To distinguish the routines, Normalize to Peak value creates MVC values, Normalize to MVC Stack loads MVC values for the normalization of other trials of the same subject.

- **Values from other records**: This method accesses normalization values found or applied from an "other" trial. Only trials of the same subject are listed. Please verify that the proper normalization routine was performed on this "other" trial (see processing history in the *Database Record Info Section*). Typically, this is the MVC trial of one subject, which is used to calculate/find the MVC values within the maximum contraction series. If you choose a trial that was not normalized by any method, this operation cannot be performed.

In the Functional Assessment Suite, the amplitude normalization techniques will be primarily used with collected EMG signals; however, these techniques can be applied be any analog signal recording.

Delete and Delete all: You can remove a signal processing routine from the iconized list of *Selected Methods* or delete the complete list.

The other *Available Operations*, such as *Filtering*, Electrocardiography *(ECG) Reduction*, etc., are further detailed in the MyoResearch XP Master Edition Manual and are very dependent on the project purpose. As such, this POD will not explore all the available options, but these functions are explained on pages 94 – 97 of the MyoResearch XP Master Edition Manual.