Home

BITalino (r)evolution ~~Lab~~ Guide

EXPERIMENTAL GUIDES TO MEET & LEARN YOUR BIOSIGNALS

ATTENTION

The present document includes experimental protocols to be shared
with customers who have PLUX products.
This document should not be distributed through alternative routes unless the customer chose to
acquire our biosignals acquisition systems.

The information contained in this manual has been carefully checked and were made every effort to ensure its quality. PLUX reserves the right to make changes and improvements to this manual, especially during the initial phases of the creation of this document.

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HOME-GUIDE #1

ELECTROMYOGRAPHY (EMG)

Exploring Muscular Signals

1. GOALS

After this lesson you will be able to understand the basic principle of Electromyography (EMG), how a muscular signal is triggered, acquired with the given system, and explore different signals in various body locations.

In this Home-Guide you will explore the EMG signals in more detail. The main goals for this lesson will be the following:

- Perform a set of EMG acquisitions in real-time.
- Test different electrode positions to examine different muscle signals.
- Understand the change of signal triggered by changes of muscular activity.
- Getting familiar with the frequencies of interest.

2. REVIEW HOME-GUIDE #0

All information of Home-Guide #0 can be found here: HOMEGUIDE#0

Home-Guide #0 was an introduction to the hardware and software to get started with BITalino (r)evolution and OpenSignals. The main goals included performing a set of experiments using real-world biomedical data acquisition systems, understand the basics and getting familiar with such procedures. Data was acquired with the two sensors Acceleration (ACC) and Electromyography (EMG) to get a first idea of typical setup procedures and observe biosignals in real-time.

This Home-Guide #1 is a resumption of the knowledge that we have gained in Home-Guide #0 and an extension of the EMG signal analysis for gaining deeper knowledge on this specific sensor.

3. MATERIALS

OpenSingals (r)evolution software is available on: https://bitalino.com/en/software

- OpenSignals (r)evolution software
- 1 x BITalino (r)evolution Assembled Core BT
- 1 x Assembled Electomyography (EMG) Sensor
- 1-lead electrode cable (e.g., usually placed in an arm bone to be used as an internal reference)
- 2 x Gelled Self-adhesive Disposable Ag/AgCl*electrodes
- 1 x Bluetooth dongle

(a) (b) (c) (d) (e) (f)

Figure 1: BITalino (r)evolution Assembled Core BT - Front View (a) and Back View (b); Assembled Electromyography (EMG) Sensor (c); 1-Lead Electrode Cable (d); Gelled Self-adhesive Disposable Ag/AgCl electrodes (e) and Bluetooth dongle (f).

**for each experiment you must use 2 gelled electrodes for the EMG sensor. Each time you want to repeat your experiment, or each time you see the electrodes are not in a good condition it is recommended to change them for new ones. Also make sure that you clean the skin area with alcohol before adjusting the electrodes to remove skin particles and improve the skin conductivity.*

4. RELATED DOCUMENTATION

BITalino (r)evolution Quick Start Guide

BITalino Assembled Core BT Datasheet

Assembled Electromyography (EMG) datasheet

Electromyography (EMG) Sensor User Manual

5. INTRODUCTION TO ELECTROMYOGRAPHY (EMG)

5.1. EMG Basics

5.1.1. How does the Muscle work? A Physiological Overview

Let's imagine we grab an object like a glass of water. What happens in our body need to perform the grasping action with the correct angle and force to not break the glass? A series of muscles from our forearm are involved in this action. All those actions happen quite instinctive and are only possible because we have an intricate network of strategically arranged muscle fibers scattered across our body that keep us alive such as for breathing.

When we think of an action a series of events happen in our body (see Figure 2). Our brain has specific nerve cells that are responsible for motor actions. These are the upper motor neurons from which one of them can control thousands or just a few muscle fibers for large or small muscles such as the biceps or eye, respectively. When a signal is issued by the upper motor neurons it is propagated through the spinal cord to the lower motor neurons which trigger an action potential. The muscle fibers receive the action potentials voltage imbalances are originated within the muscle cells causing them to contract. The grasping of the glass is the visible result of this whole process that happens within a few milliseconds (within a blink of an eye).

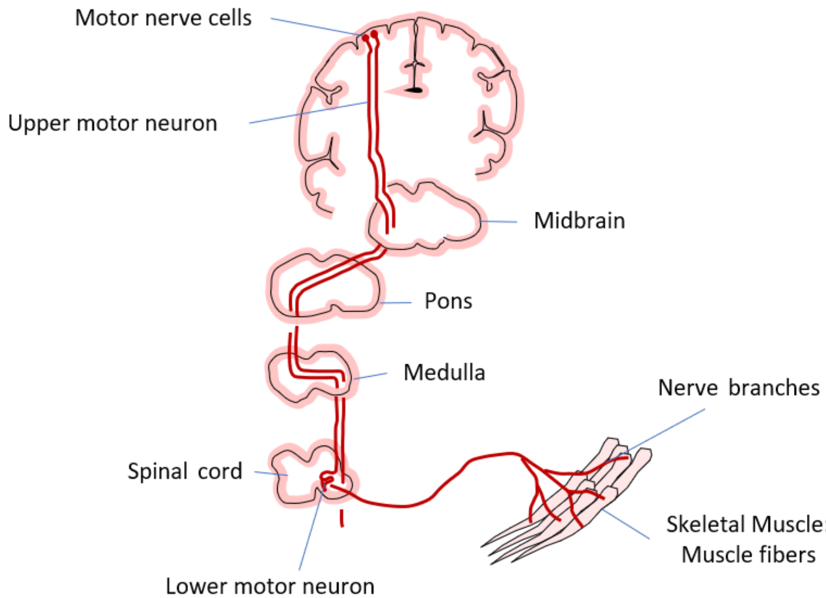


Figure 2: Path of signal (red) from the brain through the spinal cord to the muscle fibers when thinking of an action.

Across our body we have three major types of muscles with different functions such as [1]:

[1] *J. Malmivuo and R. Plonsey, Bioelectromagnetism: Principles and Applications of Bioelectric and Biomagnetic Fields, 1st ed. Oxford University Press, USA, Jul. 1995. [Online]. Available: http://www.worldcat.org/isbn/0195058232*

Smooth Muscles	• Controlled by autonomic nervous system (involuntary). • Cell length around 0.1mm. • Found in hollow organs (digestive tract, trachea, uterus, bladder).
Skeletal Muscles	• Controlled voluntarily. • Composed of large fibers from 0-01-0.1mm to 1-40mm length. • Found in organs/structures for skeleton support and motions.
Cardiac Muscles	• Controlled involuntary like smooth muscles. • When excited creates longer electrical impulses around 300ms. • Allows propagation of electrical activity to surrounding cells.

The skeletal muscles ore of most importance for us as we want to measure the muscular activity of such muscles that are just below the skin surface.

Electromyography (EMG), is derived from electro (i.e., related to or caused by electricity), myo (i.e., combining form of muscles), and graphy (i.e., descriptive outcome). It is the process to measure the muscle activity directly by measuring the electrical manifestation of the action potentials. In the following we will have a closer look on how we can measure these signals.

5.1.2. How to acquire an EMG?

EMG signals that are measured from the skin surface are in the range of milli or microvolt (depending on the muscle size and therefore the amount of muscle fibers) meaning they have up to 10000 times less voltage compared to what you need when you charge your phone. As EMG signals are sensitive to noise such as motions artefacts, they need to be processed to receive an output with good quality.

Two major methods are possible to obtain EMG signals which are the measurement from the skin surface (sEMG) or with concentric needles that are penetrated through the skin to measure the signal from the fiber level. In the following we will only consider the surface EMG and therefore will be abbreviated as EMG. To measure EMG from the skin surface, an interface between the skin and the sensor is needed that maximizes the electrical conductivity and minimizes mechanical artefacts. An example of a medical grade EMG electrode is shown in Figure 3

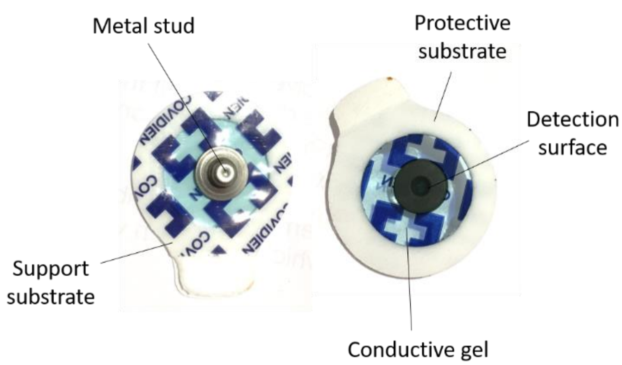


Figure 3: Anatomy of a medical grade sEMG electrode.

5.1.3. How to position the Electrodes?

EMG signals are usually measured using a bipolar setup which means that two measuring electrodes with a positive (IN+) and a negative (IN-) lead are placed on the muscle of interest to measure the voltage imbalances with respect to a baseline. Therefore, another electrode is placed in a neutral area[2]. With this bipolar setup, noise sources that occur only in the measuring and not in the reference electrode can be cancelled out by the second measuring electrode.

The two measuring electrodes should be placed along the muscle fiber, on the muscle belly and with around 2cm spacing in between them, see Figure 4 (left). The reference electrode should be placed in a neutral area such as on a bone (elbow, forehead, iliac crest, knee), see Figure 4 right).

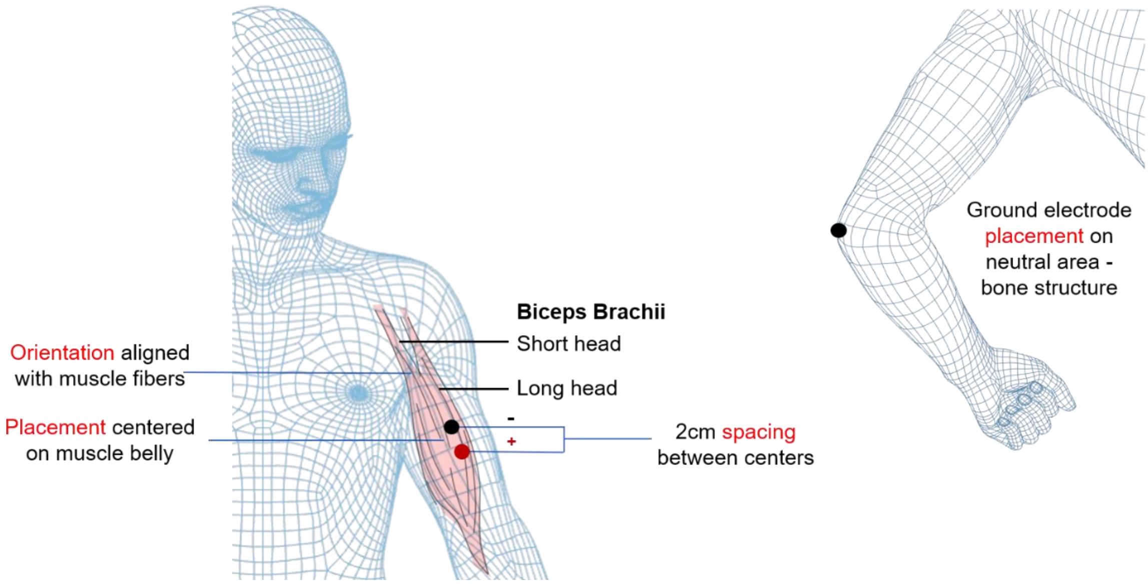


Figure 4: Electrode placement: measuring electrodes IN+ and IN- leads (left) and reference lead (right).

5.1.4. How to process the Signal?

As EMG signals have a very low amplitude (millivolt-level) it is necessary to amplitfy them with a gain of 1000x to a scale that is less sensitive to noise and can be further processed by an Analog-to-Digital Converter (ADC). To remove unwanted noise sources or limit the sensor output it is also helpful to filter the signal to a specific frequency band of interest that still contains all the information of muscular signals such as 20-450Hz that is typically used for surface EMG.

As the signal undergoes signal conditioning steps before reaching the ADC, we need to consider some teps to convert the digital code to its physical unit. For EMG signals sampled with BITalino, the digital codes produced by the 10-bit ADC range between 0 − 1023, which, considering the 3.3V operating voltage of the ADC, corresponds to 0 − 3.3V with a quantization step size of 3.3V /1024 ' 3.223mV (voltage measured at ADC input) .Due to the amplification done at the senasor level, the signal reaches the ADC with values of 0 - 3.3V.

[2] *J. V. Basmajian and C. J. De Luca, Muscles Alive: Their Functions Revealed by Electromyography, 5th ed. Williams & Wilkins, 1985.*

5.1.5. How to acquire an EMG with BITalino?

There are a number of options that can be used to interface the sensor with the body, but the most standard way is to use a cabled connection between the pre-gelled electrodes placed at the body surface and the sensor. Though, the BITalino EMG sensor is directly connected to the electrode snaps (see Figure 5) enabling the already pre-asslebled electrode distance of 2cm. The IN+ & IN- pins are the input from the signal leads (inside your green casing, see Figure 5), while REF is the input for an optional reference cable when not assembled.

Figure 5: Assembled EMG sensor form the inside and pins for electrode connections. Top (left), bottom view (right).

Let's have a look at how an EMG signal looks like. Figure 6 shows an EMG signal acquired with a BITalino assembled to measure the muscular contraction of the muscle biceps brachii (see task in Home-Guide #0). The resting phases show a baseline around 0mV and the two activation phases show different amplitudes of around ±0.5mV and ±0.75mV, respectively. To receive this signal the following measures were taken into consideration: a new electrode was used, the skin was cleaned before, all three electrodes were completely sticking on the skin and not peeling off, the devices were not charging while acquisition, the Bluetooth adapter was used, the cables (sensor and reference) were connected to the analogue ports 1 and 2.

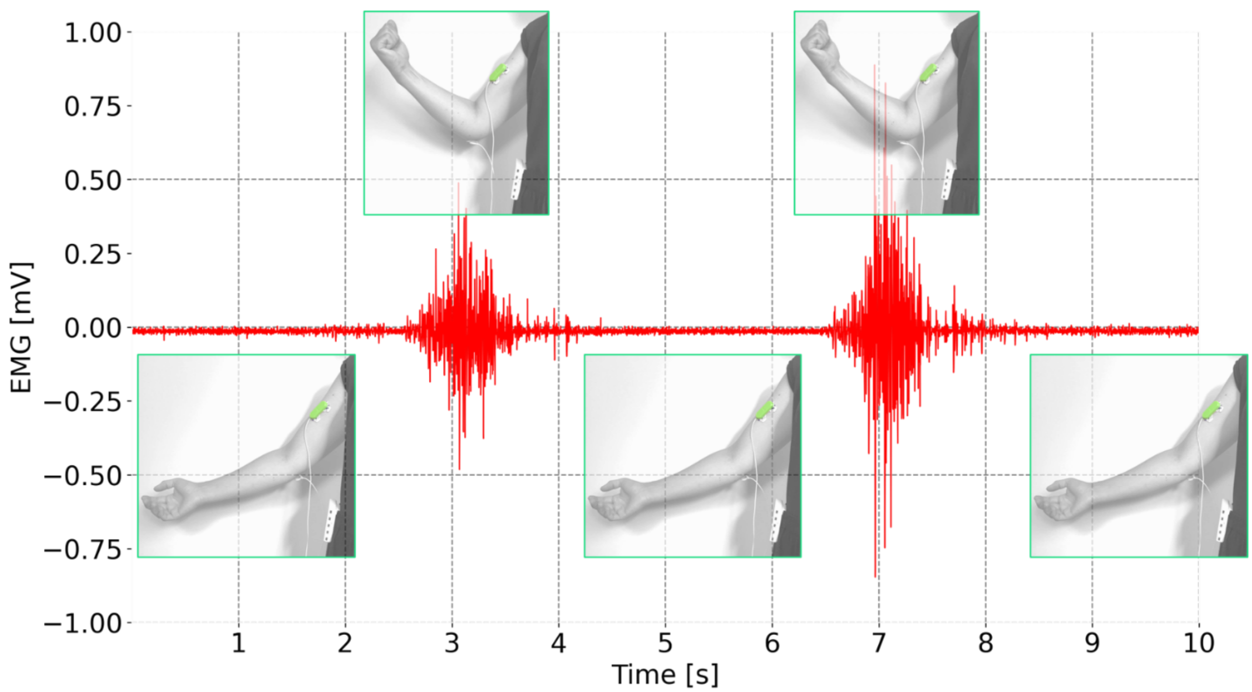
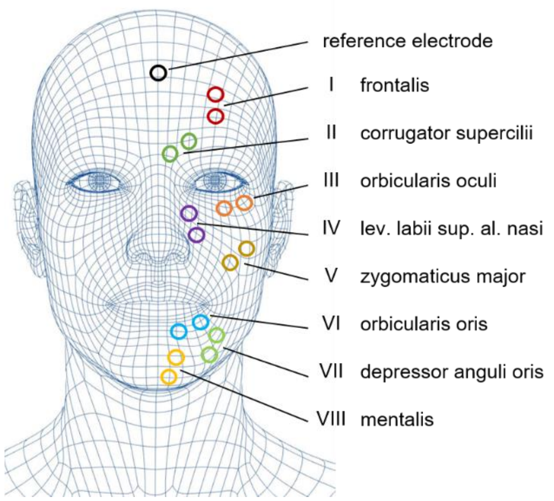


Figure 6: EMG signal acquired with BITalino assembled: 3 resting and 2 muscular contraction phases.

5.2. Applications – What is EMG used for?

A very interesting body region to measure EMG signals is the face with the facial muscles, which give an insight to emotions and hence are the richest source of information for the affective state. Facial expressions can be analyzed by experts or automated systems. Medical fields such as movement and rehabilitation research apply facial EMG. Some examples are for neurodegeneratice diseases such as stroke, Parkinson´s disease and ALS [3]. Electrode positions for specific facial muscles to measure an EMG signal are shown in Figure 7 (left). In order to contract those muscle goups, specific emotions or actions must be performed, which are listed in Figure 7 (right) [4].



Emotions	Muscles	Produced Actions
Happiness	III & V	• Closing eyelids • Pulling mouth corners upward, laterally
Surprise	I	• Raising eyebrows & upper eyelid
Fear	I & II	• Raising / lowering eyebrows • Raising upper eyelid
Anger	II & III	• Lowering eyebrows • Raising upper eyelid • Closing eyelids
Sadness	I & II & VII	• Raising / Lowering eyebrows • Depressing lip corners
Disgust	IV	• Raising upper lip • Wrinkling nasal skin

Figure 7: Electrode placements to measure muscle activity of facial muscle groups with EMG (left), and Facial muscles involved in specific emotions and actions (right).

[3] https://imotions.com/blog/facial-electromyography/ 02.09.2020

[4] Boxtel, Anton van. "ADVANTAGES AND DISADVANTAGES OF FACIAL EMG AS AN INDEX OF AFFECTIVE." (2010).

6. PROTOCOL

6.1. Body Sensor Setup on various Muscle Groups

We will have a deeper look at various muscle groups to better understand each functionality and differences. Let us start with the flexor carpi radialis and review what we have already been acquiring in the last session. Were you able to perform a muscular contraction and acquire a signal with low noise?

6.1.1. Flexor carpi radialis (forearm)

The functionality of the flexor carpi radialis can be tested with EMG sensors for example for the purpose of rehabilitation. To measure muscular activity of the muscle flexor carpi radialis, the two measuring electrodes must be placed along the muscle fiber, see Figure 8 (left) and on the muscle belly [5]. The placement of the assembled EMG sensor is illustrated in Figure 8 (right) in which the reference electrode is positioned on the elbow.

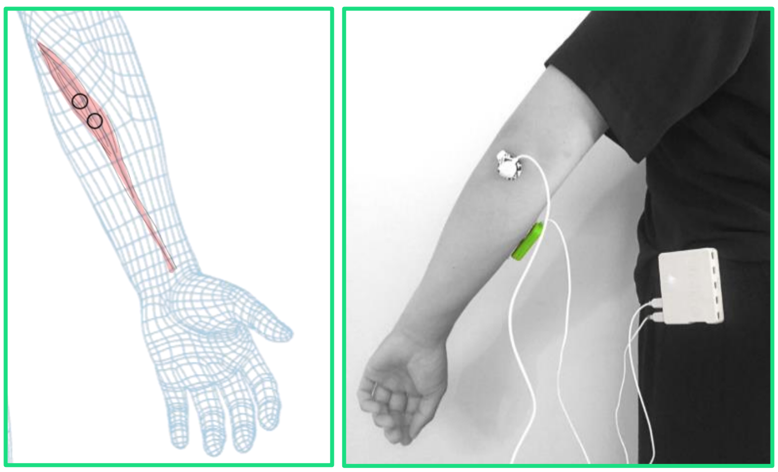


Figure 8: EMG electrode positioning for flexor carpi radialis (left, marked in red) and positioning of the assembled EMG sensor plus reference electrode (right).

To perform a muscular contraction of the flexor carpi radialis, an extension of the hand must be performed, see Figure 9 (right).

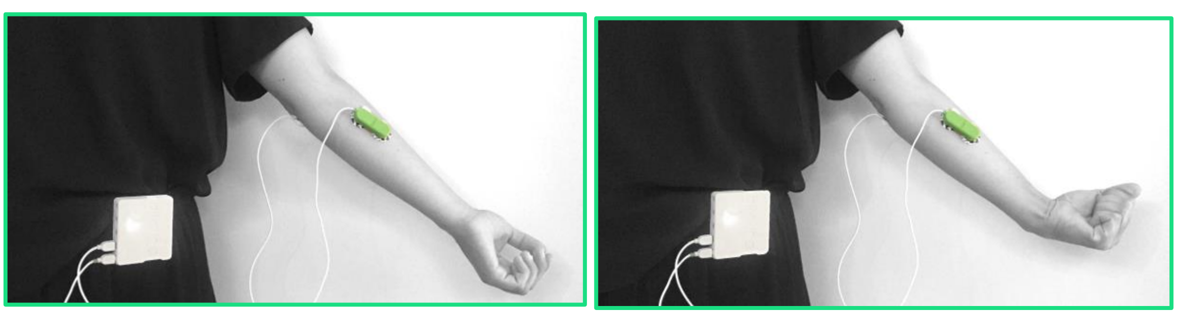


Figure 9: Measuring the muscular activity of the muscle flexor carpi radialis in relaxing state (left) and activation (right) with electrode placement along the muscle fibre (green) and reference electrode on the elbow.

[5] *Criswell, Eleanor. Cram's introduction to surface electromyography. Jones & Bartlett Publishers, 2010.*

6.1.2. Abductor pollicis brevis (thumb)

The next muscle we want to examine is the abductor pollicis brevis which is located at the thumb of the hand. It is a muscle to perform abduction of the thumb. The functionality of this muscle can be examined using EMG electrodes for example for rehabilitation purposes. The two measuring electrodes are positioned along the muscle fibre as illustrated in Figure 10.

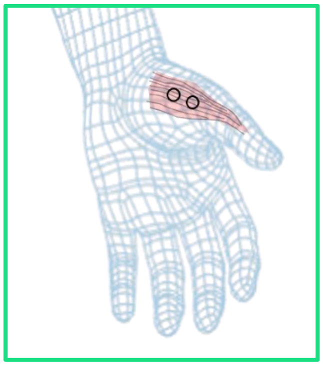


Figure 10: Electrode placement for the abductor pollicis brevis (marked in red).

The electrode positioning of the assembled EMG as well as the reference electrode are shown in Figure 11 in which the muscle is in a relaxed state (left) and is being contracted (right) while abduction of the thumb.

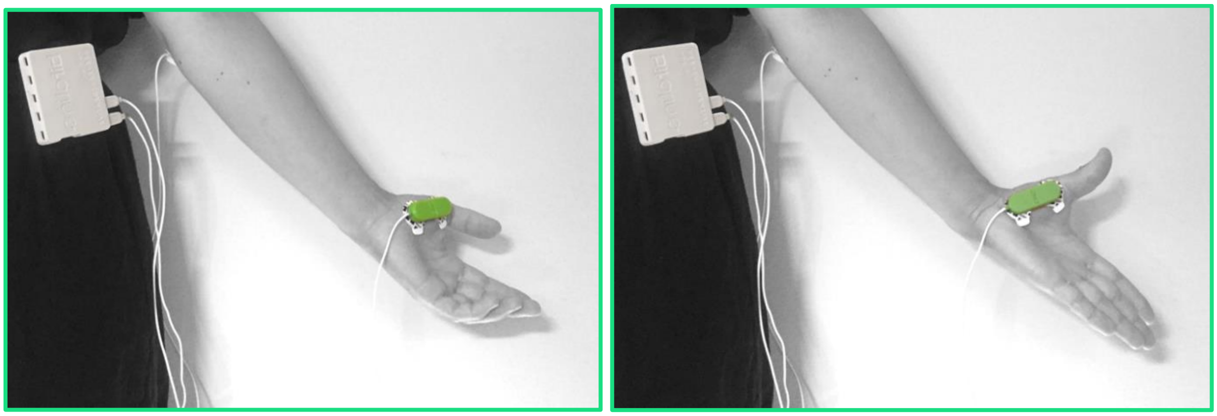


Figure 11: Positioning of the assembled EMG sensor and the reference electrode for measuring activity of the abductor pollicis brevis muscle while resting (left) and contraction by abduction of the thumb (right).

6.1.3. Trapezius Descendens (upper)

The upper muscle trapezius descenders is examined for clinical cases such as headaches, shoulder pain or strain injuries. For these purposes, the functionality of the muscle can be tested, or specific exercises performed with the help of the EMG signals. The general electrode placement for measuring muscular contractions of the upper trapezius are illustrated in Figure 12 (left) in which both measuring electrodes are positioned along the muscle fibre. The positioning of the assembled EMG sensor as well as the reference electrode are shown in Figure 12 (right).

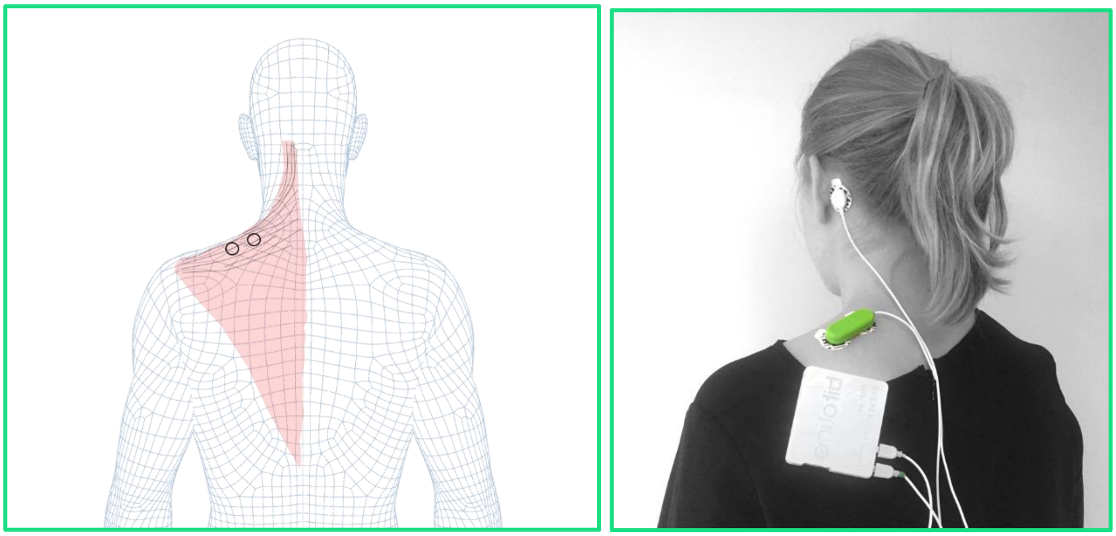


Figure 12: Electrode position for upper trapezius (marked in red) and assembled EMG sensor position with reference electrode (right).

Hint
Check out http://www.seniam.org/ for recommended sensor placements on individual muscles.

6.1.4. Zygomaticus major (happiness)

The functionality of the zygomaticus major can be tested with EMG sensors for example for rehabilitation of facial muscles or for psychophysiological studies. The electrode placement for this muscle is shown in Figure 13.

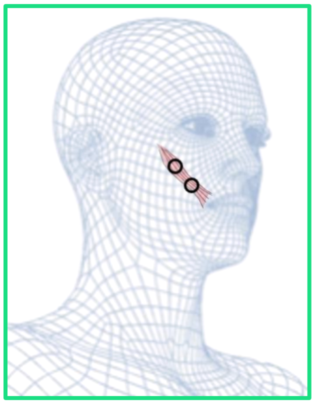


Figure 13: Electrode placement for the zygomaticus major (marked in red).

Activating the muscle zygomaticus major can be performed by retracting and elevating the lips (e.g. smiling), see Figure 14 (right) [7]. The placement of the assembled EMG as well as the reference electrode are shown in Figure 14 (left).

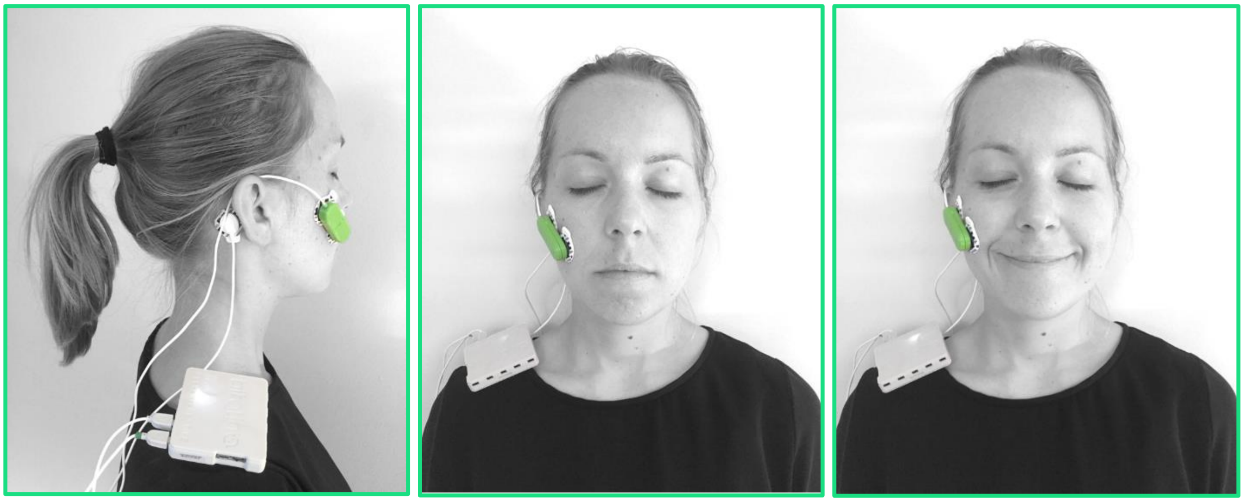


Figure 14: Measuring the muscular activity of the muscle zygomaticus major. Electrode placement (left) along the muscle fiber (green) and reference behind the ear. Relaxed state (middle) and muscular contraction with smiling (right).

6.2. Data Acquisition

Review: Follow the device setup (1-3) as already explained in Home-Guide #0 and continue with steps 4-8.

1. Connect your BITalino (r)evolution Core BT
2. Testing your set-up
3. Live Muscles with Electromyography (EMG)
4. Start recording a signal baseline with low noise and no muscular activation for 30 seconds.
5. Repeat a cycle of CONTRACTION-RELEASE-REST five times, maintaining the contraction for two seconds and resting for two seconds; try to start with a low intensity contraction and gradually increase the level in each repetition, in such way that the last corresponds to your maximum voluntary contraction ability.
6. Record another baseline phase of 30 seconds.
7. Perform several short consecutive activations (each 1 seconds) followed by one contraction over several seconds (10 seconds).
8. Stop the recording and save your data.

6.3. Repeat Activities for the different Muscles.

Preform the data acquisition steps of section 2 (4-8) on various muscle groups:

1. Flexor carpi radialis (forearm)
2. Abductor pollicis brevis (thumb).
3. Trapezius descendants (upper).
4. Zygomaticus major (happiness) - choose a facial muscle of your interest.

For additional information review the last Home-Guide which is available here:

HOMEGUIDE#0 and the documentation available on the previous section "RELATED DOCUMENTATION"

IMPORTANT NOTES:

Learn more about recommended EMG electrode positions at:
Recommended sensor placements on individual muscles
Learn more about the EMG specifications and working principle on the datasheet available at:
Electromyography (EMG) Assembled Sensor Datasheet

6.4. Elaborate your Report and answer the Quiz.

Write a report on the performed acquisitions of each muscle group, following the acquisition steps mentioned in section 2. Finally, fill out the quiz and check out the additional documents for help.

7. QUIZ

In this section you can find some questions for you to work on during your Home Session and to explore the EMG sensor.

Q1. Which are the significant frequencies for EMG acquisitions? Are they the same in all body areas such as facial area?

Q2. Which kind of filter is essential when working with EMG signals? Why do we need to apply such a filter?

Q3. How does the amplitude differ in each muscular contraction? Is there a difference for body locations?

Q4. Show a screenshot of a relevant portion of Electromyography (EMG) data within the experiment proposed on Section D of a facial muscle of interest. Does this signal correspond to what you expected? Why? Which emotion and action did you perform to trigger the muscle? Which muscle did you trigger?

Q5. To the best of your knowledge, does the EMG amplitude equal to the amount of force that you have generated with your muscle?