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Scientific Research

Feasibility Assay for Measure of Sternocleidomastoid and Platysma Electromyography Signal for Brain-Computer Interface Feedback

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Abstract

A feasibility assay is conducted for electromyography measure in sternocleidomastoid and platysma, tenting to use it on Brain-Computer Interface (BCI) feedback. It is proposed a case of study for four healthy subjects with an average of 35 years old, two females and two males. Methodology proposed includes signal acquisition and processing with feature extraction of RMS, Mean and Variance. The data are acquired with the AD board NI USB-6009, interfaced with LabView and processed in MatLab. An uncertainty analysis was made obtaining a system uncertainty of ±2.31 mV. ANOVA analysis was done, with a Randomized Complete Block Design (RCBD) experiment and interaction of factors and residues obtained with the software Minitab.

Keywords

Electromyography, Feature Extraction, Uncertainty, Statistical Analysis, Factors Interactions

1. Introduction

Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes. The smallest functional unit to describe the neural control of the muscular contraction process is called a Motor Unit. The EMG-signal is based upon action potentials at the muscle fiber membrane resulting from depolarization and repolarization processes. The extent of this Depolarization zone is described in the literature as approximately 1 - 3 mm^2. Because a motor unit consists of many muscle fibers, the electrode pair "sees"

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the magnitude of all innervated fibers within this motor unit—depending on their spatial distance and resolution. Typically, they sum up to a Motor unit action potential (MUAP), which differs in form and size depending on the geometrical fiber orientation in ratio to the electrode site [1].

A Brain-Computer Interface (BCI) system allows to communicate humans and devices without need of sensors in others parts of the body or the muscular system. Although, they are a promising tool for persons with severe palsy conditions like neurodegenerative. Facial electromyography (EMG) contamination of the electroencephalography (EEG) signals is a largely unresolved issue in brain-computer interface (BCI) research. Mu and beta rhythms are widely used in the literature and they lie in the frequency range that is susceptible to electromyography (EMG) contamination [2]. Also, signals from the muscles related to the movement can provide a feedback system, with precious information for taking right decisions concerning for example, to a wheelchair movement. That's why the main objective of this research is to measure the EMG signal of the sternocleidomastoid (SCM) and platysma (PM) muscles in order to validate the feasibility of their use. The MUAPs within the pick-up area of electrodes can be observed noninvasively by using electrodes affixed to the surface of the skin. These signals are stochastic in nature and can be represented by a Gaussian distribution function. The amplitude of signal ranges from 0 to 10 mV (peak to peak) or 0 to 1.5 mV (RMS). The usable energy of signal is limited to 10 to 500 Hz frequency range, with dominant energy being 50 to 150 Hz range [3].

Literature recommends band pass filtering settings from 10 Hz high-pass up to at least 500 Hz low pass; most of the surface EMG frequency power is located between 10 and 250 Hz. After this, other techniques are applied to prepare the signal for feature extraction; therefore these characteristics are introduced in computational intelligence systems (e.g., Support Vector Machines, Artificial Neural Networks and Linear Discriminant Analysis) that turns the signal information into the movement that is been performing [4] [5].

This paper presents an experimental section with the methodology used to obtain the data, a short overview of the materials employed and the data processing, an approaching to the uncertainty estimation of the measuring system and the discussion of the results.

2. Experimental Section

In this research we want to validate if three of the characteristics used in computational methods, obtained by EMG feature extraction techniques, change in presence of a paradigm, and by changing the electrode's position. Let's consider three factors that may influence the response variable (EMG characteristic): Paradigm (A), Subject (B) and Position (C).

We propose a Randomized Complete Block Design (RCBD) experiment, in which we fix the B factor and produce a complete randomization for each block, containing all the treatments [6].

The paradigm factor has four levels corresponding to the movements of the neck: Right (1), Left (2), Ahead (3) and Back (4); and related with the basics actions that a wheeling chair user has to accomplish. The third factor, position of the electrodes has four levels because the interest is to validate different positions related to the head's movement like: PM—Right (1), PM—Left (2), SCM—Left (3) and SCM—Right (4). The second factor is subjects and is blocked because the lack of time between measures that could compromised the veracity of the experiment, that's why this factor was blocked and the trials randomized for each subject: B1 (1), B2 (2), B3 (3) and B4 (4).

Finally, is proposed a case of study for four healthy subjects with an average of 35 years old, two females and two males having no history of muscle problems, as described by the methodology of the essay (**Figure 1**).

2.1. Materials Description

To obtain useful information from EMG signal it is required that any detecting and recording device processes the signal linearly, that's why after the surface electrodes, the signal is presented to an active electrode with differential amplification (Instrumentation Amplifier) for more than 500 times before the analog filtering stage (Electromyograph). At this moment, the signal is digitalized by an A/D board for the computer acquisition controlled by an interface application (LabView) as seen on **Figure 2**.

Eight electrodes are located in the muscles of interest, two at right and two at left by muscle (SCM, PM), adding the reference electrode in the forehead (**Figure 3**). At the moment of acquisition, it's only recorded the channel of the combination that it's been evaluating. The application interface is set to a sampling frequency of 1000 Hz and about nine seconds of time are recorded (9000 samples). Using a function implemented in MatLab,

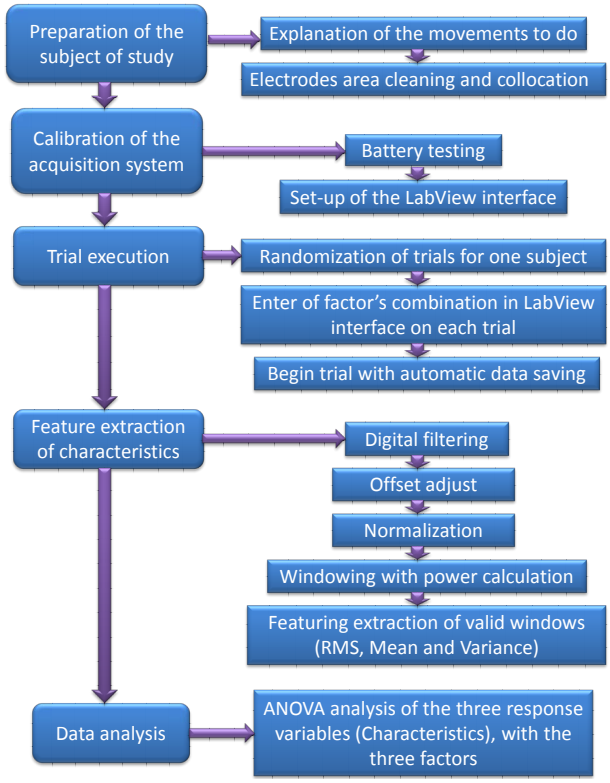


Figure 1. Methodology diagram of the assay propose for the EMG measure.

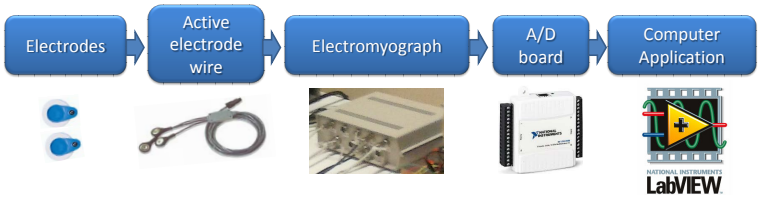


Figure 2. Block diagram of measuring channel of EMG.

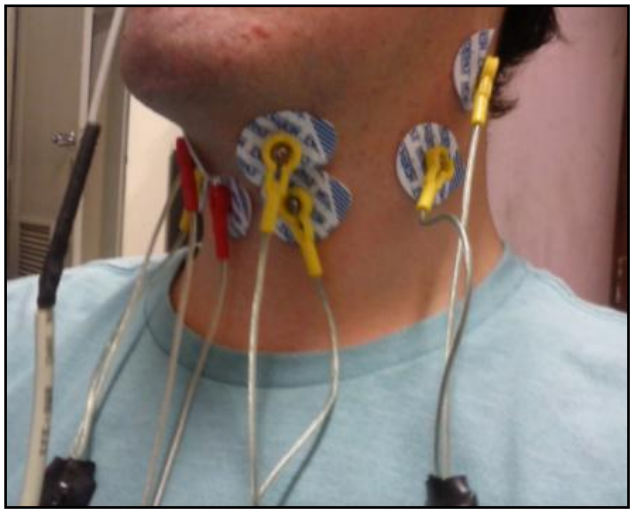


Figure 3. Subject's neck showing electrodes positions.

the measuring combinations are rearranged inside a single subject's trial, granting the randomization inside the block of subject's trial (e.g., Paradigm Right with SCM-Left Position measuring). The movement to be fallow by the subject is displayed in the center of the interface, and the muscle reaction is recorded.

All the data is recorded in archives and they are processed later by the MatLab function created for the test. This function loads the archive containing the register and at first it's filter with a FIR filter band pass with butter approximation. Fourier transform is applied to the register for obtain the spectrum before and after filtering.

The register's offset component is eliminated by its calculation and subtracted from it (Equation (1)); also this vector is normalized by the computation of the register's maximum and its division (Equation (2)). The mean is obtained and used for the threshold's determination according with the literature and the research group results [7].

$$\mathrm{CD} = \sum_{i=1}^{N} \frac{Xdc}{N} \tag{1}$$

$$X = Xdc - \mathrm{DC} \tag{2}$$

Depending of the value of the register's maximum the threshold is establish and used a posteriori for the valid windows determinations by comparing the window's power with the threshold obtain [8]. After eliminate the offset and normalize, we have the next register in time (**Figure 4**). For the windowing method is selected a window of 250 ms, and the validation of movement in the window is possible by comparing the threshold with the power calculated in Equation (3). Then, the EMG's characteristics: RMS, Mean and Variance are obtained from the valid windows. At the end we get these values as we can see in **Figure 5**. Finally the features are calculated and store into a table for ANOVA and statistical analysis.

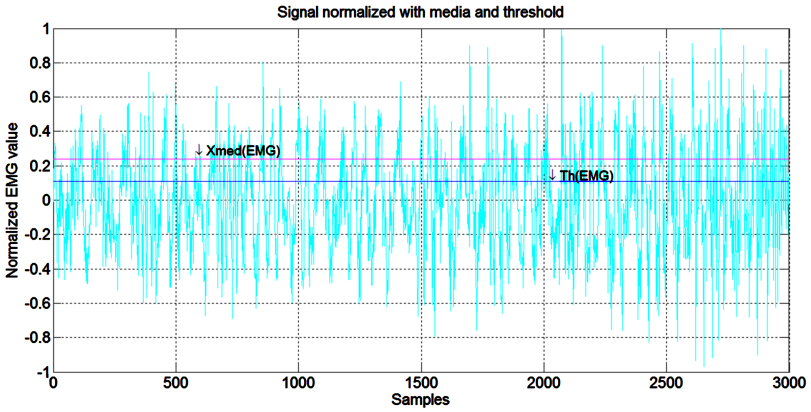


Figure 4. Register of EMG normalize with Mean (Xmed) and Threshold (Th).

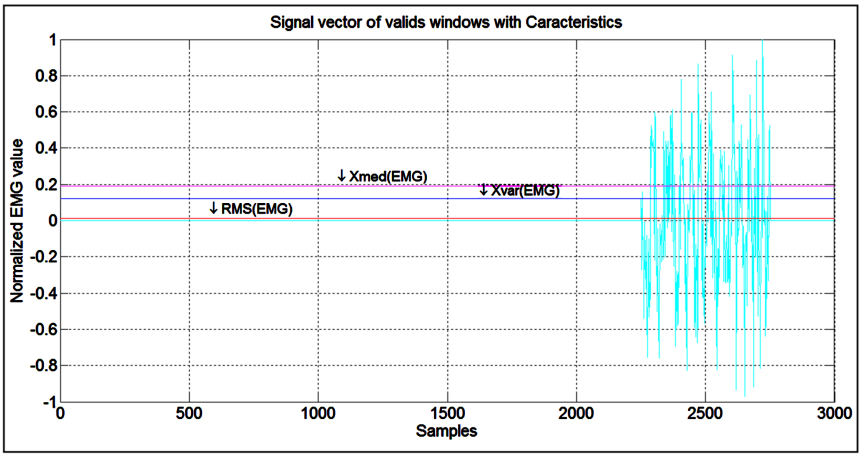


Figure 5. Window of EMG of valid movements with RMS, Mean (Xmed) and Variance (XVar).

2.2. Uncertainty Estimation

The uncertain analysis for the measuring channel is done taking into account the principals sources uncertain and errors. A classical analysis is proposed making an estimation of the majority of the source represented in the cause-effect diagram from **Figure 6**. As seen in diagram of **Figure 6**, there are five principal sources that contribute to the uncertain estimation on the system. For the estimation of the Instrumentation Amplifier (IA) contained in each active electrode (four wires for the experiment) and the electromyograph voltage characterizations were developed, measuring with a Digital Oscilloscope which uncertainty is too evaluated. The A/D board is a 13 bits USB data acquisition, which resolution is reviewed. The electrodes are MediTrace ECG Conductive Adhesive Electrodes disposables and besides are identified as an error source, and knowing that has a normal distribution, we don't have information for their uncertain estimation.

First of all let's analyze the IA:

Affectation of common mode voltage to 60 Hz (CMRR): This source has it origin in the common mode voltage increasing when is in presence of 50 Hz or 60 Hz of industrial national power supply [8]. Let's assume an uncertainty Type B with rectangular distribution:

$$\begin{aligned} V_{\text{out}} &= \frac{G \times V \text{ cm}}{\log^{-1}\left(\dfrac{\text{CMRR}}{20}\right)}, \\ V_{\text{out}} &= \frac{981.39 \times 400 \text{ mV}}{\log^{-1}\left(\dfrac{120 \text{ dB}}{20}\right)} = 0.3925 \text{ mV}, \\ u &= 0.3925 \text{ mV}. \end{aligned} \tag{3}$$

Repeatability of the V_{out} measure (IA): One group of measures is analyzed for the IA characterization at 150 Hz. The entrance had been changed to obtain the group of values of V_{out}. Let's assume an uncertainty Type A with normal distribution:

$$s = \sqrt{\frac{\sum |Xmes - Xi|}{n-1}} = 1.0323 \times 10^{-3} \text{ mV}, \quad s = 1.0323 \times 10^{-3} \text{ mV} \tag{4}$$

Repeatability of the electromyography (EMG): For this device that is compound by four operational in filter implementation, a characterization for five frequencies (50, 70, 100, 150 and 200 Hz) is developed obtaining data at V_{out} that support a gain very close to 1, and maintain plane response at these frequencies. Let's assume an uncertainty Type A with normal distribution:

$$s = \sqrt{\frac{\sum |Xmes - Xi|}{n-1}} = 1.123 \text{ mV}, \quad s = 1.123 \text{ mV} \tag{5}$$

Resolution of the Oscilloscope vertical channel (OSCRES): only is study this incidence because that the kind of measures are been made are in voltage. Let's us assume an uncertainty Type B with rectangular distribution.

$$\begin{aligned} a &= 2 \text{ mV/div}, \\ \frac{2 \text{ mV}}{10(\text{sub} - \text{div})} &= 0.2 \text{ mV}, \quad u = 0.1 \text{ mV}. \end{aligned} \tag{6}$$

Calibration Certificate of the Oscilloscope vertical channel (OSCCAL): it owns a calibration certificate that introduces to the system an uncertainty Type B with normal distribution [9]. For a 95%:

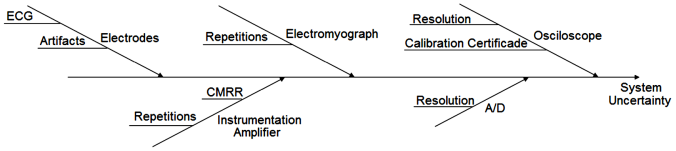


Figure 6. Cause-effect diagram of the uncertainty sources from the EMG measuring system.

$$\Delta y = 1.0033 \pm 0.00352 \quad \text{with} \quad k = 1.96,$$
$$u = 0.00352/2 = 1.76 \times 10^{-3}\ \text{V} = 1.76\ \text{mV}. \tag{7}$$

Resolution of the board NI USB-6009 (AD): For this analysis we calculate the minimum detectable change (Mdc) due to the resolution of the system [10]. As the board is used as single-ended, it has a resolution of 13 bits, and a dynamic range of ±10 V (Edr). Let's us assume an uncertainty Type B with rectangular distribution.

$$\text{Mdc} = \frac{\text{Edr}}{G \times 2^{13}} = \frac{\pm 10\ \text{V}}{1 \times 2^{13}} = \pm 1.2\ \text{mV} \tag{8}$$

The combined uncertainty was obtained by:

$$U_c = \sqrt{U(\text{CMRR})^2 + U(\text{IA})^2 + U(\text{EMG})^2 + U(\text{OSCRES})^2 + U(\text{OSCAL})^2 + U(\text{AD})^2} \tag{9}$$

$$U_c = 1.18\ \text{mV},$$
$$V_{\text{eff}} = \frac{(Uc)^4}{\sum \frac{Ui^4}{Vi}}, \tag{10}$$
$$V_{\text{eff}} = \frac{(1.18\ \text{mV})^4}{\frac{(0.2433 \times 10^{-3}\ \text{mV})^4}{17} + \frac{(0.25\ \text{mV})^4}{19}} = 9430.22.$$

As the V_{eff} is superior to 30, we calculate the coverage factor k by the normal table, looking for the z value for a confidence level of 95%, it will be $k = 1.96$ for an expanded uncertainty like Equation (11):

$$\text{Uexpanded} = k \times UC, \quad \text{Uexpanded} = 2.31\ \text{mV} \tag{11}$$

After this we can elaborate a table with the principal uncertainties of the system (**Table 1**). Finally the data acquire by the system can be expressed with an uncertainty of ±2.31 mV .

3. Results and Discussion

First of all, we corroborate that data obtained fallows a Normal distribution and are independents. To achieve this, we build a histogram for each of the features (**Figure 7** shows only one analysis). The graph's likeness to normal behavior is considered sufficient as premise to perform an ANOVA analysis. According with the obtained data from the feature extraction we can form tables for the three characteristics. This analysis, also named variance analysis, allows determining which factors and combinations of they, are related [6]. To have a better picture of data behavior, residual plots are obtained (**Figure 8** shows only one analysis).

In the graphic of **Figure 8**, the residual histograms show a normal behavior. The residual plots versus fits, systematic patterns are not evident and random pattern of residuals is seen on both sides of 0. As was defined in

Table 1. Uncertainty data estimation resumes of the system sources.

Sources	Estimative	Type	Distribution	Divisor	Uncertainties
Affectation of common mode voltage to 60 Hz (CMRR)	0.3925 mV	B	Rectangular	$\sqrt{3}$	0.2266 mV
Repeatability of the vout measure (IA)	1.0323×10^{-3} mV	A	Normal	$\sqrt{18}$	0.2433×10^{-3} mV
Repeatability of the vout electromyograph (EMG)	1.123 mV	A	Normal	$\sqrt{20}$	0.25 mV
Resolution of the oscilloscope vertical channel (OSCRES)	0.1 mV	B	Rectangular	$\sqrt{3}$	0.0577 mV
Calibration certificate of the oscilloscope vertical channel (OSCCAL)	1.76 mV	B	Normal	1.96	0.8979 mV
Resolution of the board NI USB-6009 (AD)	1.2 mV	B	Rectangular	$\sqrt{3}$	0.6928 mV
Combined uncertainty	$Uc = 1.18$ mV		Coverage Factor		$k = 1.96$
Effective degrees of freedom	$V_{\text{eff}} = 9430.22$		Expanded Uncertainty		$U_{\text{exp}} = 2.31$ mV

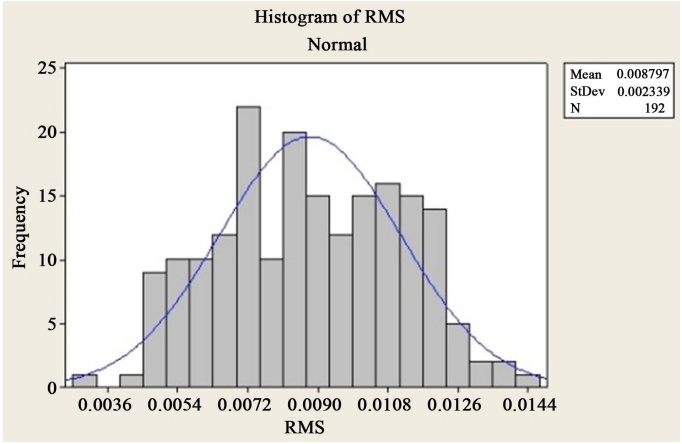


Figure 7. Histogram of the EMG extracted features: RMS.

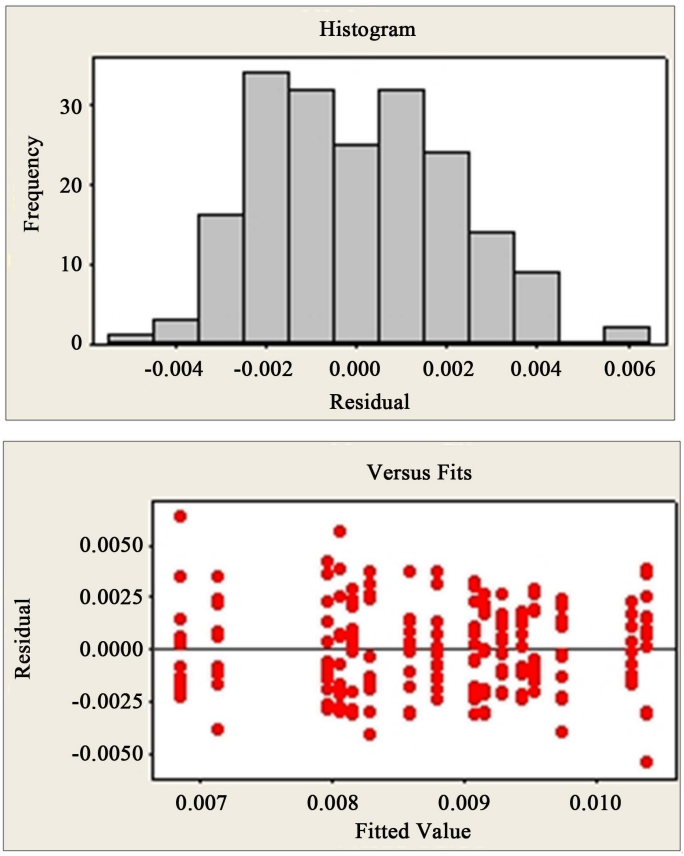
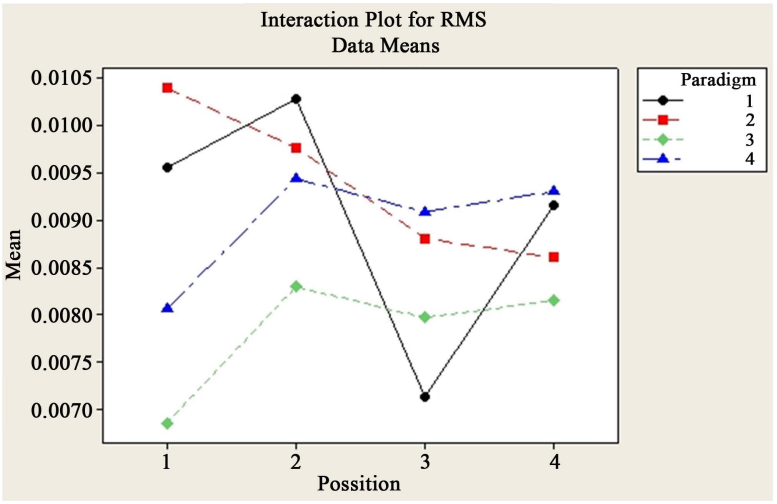


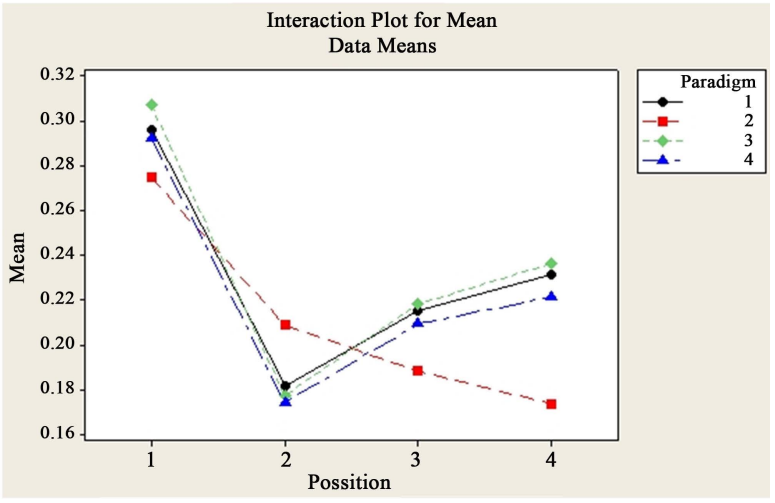
Figure 8. Residual plots for the EMG extracted features: RMS.

Section 2, a RCBD experiment is made were the B factor (Subjects) is blocked. In this case, the response variable RMS of the EMG signal change with the A, C and AC factor's combination. Other evaluations are made for the EMG Mean and EMG Variance. The response variables Mean and Variance of the EMG signal, change with the A, C and AC factor's combination, that means, the A, C factors and their interactions are significant, and further statistical analysis can be taking for the three characteristics obtained. The factors Paradigm (A) and Position (C) can be plotted for their interactions analysis for the three characteristics.

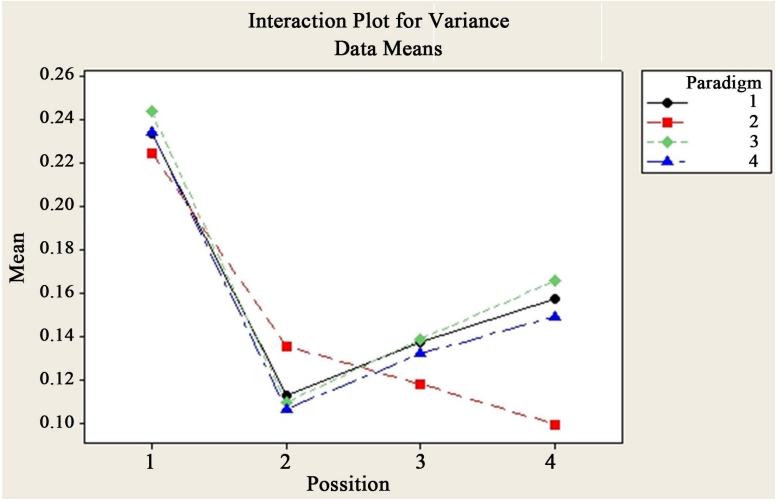
As we can see, **Figure 9(a)** (RMS) shows that the Paradigm's level: 3 and 4, move ahead and back respectively, doesn't interact, changing equally with the position; opposed to the behavior of the others two Paradigms'



(a)



(b)



(c)

Figure 9. Interactions plots between the paradigm and the electrode's position for the EMG extracted features: (a) RMS; (b) Mean; and (c) Variance.

level: move Right (1) and Left (2), that have a crossover interaction, showing variation with the electrode's position. It means that the lateral movements (Right and Left) are more influents than the other two (Ahead and Back). We can appreciate also how Positions 1 (PM—Right) and 2 (PM—Left), change equally with the four paradigms, contrary to the other two: 3 (SCM—Left) and 4 (SCM—Right) that interact in this values with all the paradigms. This last aspect is also appreciated in **Figure 9(b)** (Mean) and **Figure 9(c)** (Variance). It could indicate that SCM muscle is most influent for EMG signal acquisition for the paradigm's translation, than PM.

4. Conclusion

This research tries to validate the feasibility of the electromyography of the study muscles and the paradigms tested. In the attempt, a new interface for signal acquisition was developed, as well as a code implemented, for feature's extraction like RMS, Mean and Variance. Instead of the fact that the influence of the paradigm and position factors over the three response variables is significant, the results showed that the obtained sternocleidomastoid muscle signal is much stronger and more significant, than the one acquire from the Platysma. Also the paradigms of lateral movements have more interactions than the other levels, suggesting a paradigms change. It is recommended further assays with other paradigms including the lateral movement's studies in this research, and the use of the SCM muscle for BCI feedback.

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