Classification of different movements executed with the same upper limb through EEG signals.

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Objective:

The main objective of this research is to evaluate an EEG signal classification model to determine what movement is executed by a healthy test subject with the right upper limb.

Methods:

The electroencephalography signals corresponding to 15 test subjects were acquired, pre-processed, and processed to evaluate the classification between movements executed by a test subject with his right upper extremity.

- **Experimental protocol:**

To acquire the raw signal data, an experimental protocol was implemented, guiding test subjects through sequences of visual stimuli involving attention, execution, and rest phases. Figure 1 illustrates the images presented to the subjects, along with the respective duration times for each image. This protocol facilitated the acquisition of electroencephalography signals during 120 trials within each session, resulting in the recording of 30 trials per class for each participant.

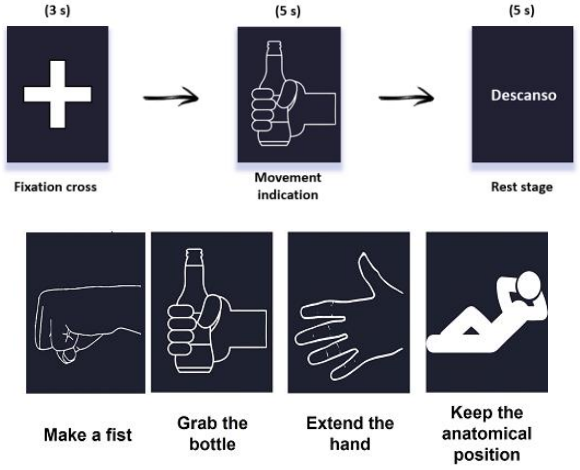


Fig 1. Images used in the experimental protocol.

Each trial lasted 13 seconds (as depicted in Figure 1), divided into three distinct stages: attention, execution, and rest. During the attention phase, a fixation cross is displayed, signaling to the subject to focus on the upcoming movement. This visual cue lasts for 3 seconds, during which the subject is instructed to refrain from blinking or making sudden movements. Following the fixation cross, a visual stimulus is presented for 5 seconds, specifying the movement to be executed—this could involve making a fist, extending the hand, or maintaining stillness. During the execution stage, the subject is directed to perform the designated movement with maximal force, sustaining it until the rest instruction appears. The final phase of a trial encompasses a 5-second resting period, denoted by an image bearing the word "descanso," indicating to the subjects that they can blink, adjust their position for comfort, and prepare for the subsequent trial commencing with the next fixation cross.

- **Data Collection:**
  The data for this research was gathered using the high-performance neuroscience research system, the g.HIamp by g.Tec. This device allowed for the simultaneous recording of 32 EEG channels at a sampling frequency of 1200 Hz. The specific channel configuration utilized in this study is illustrated in Figure 2.

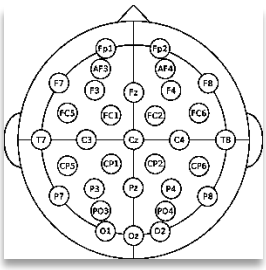
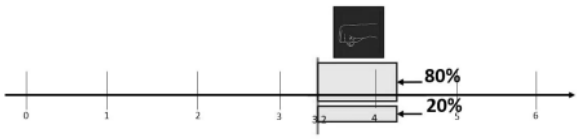


Fig 2. EEG electrodes configuration

Offline Analysis:

For the offline analysis, the Monte Carlo Cross-validation technique was employed. This involved partitioning the data into a training set, which encompassed 80% of the recorded trials, and a test set, which comprised the remaining 20%. This process was iterated 500 times, with the data sets being randomly defined for each iteration. Feature extraction was conducted using two distinct analysis windows, as depicted in Figure 3. The analysis window for the fixation cross was situated in the final second of that phase, while the analysis window for task execution spanned from 3.2 seconds to 4.2 seconds—precisely 0.2 seconds after the presentation of the image indicating the execution of the movement.



Results:

Table 1 shows the average Accuracy of the 15 test subjects when evaluating a binary classification system between the proposed classes. In this study, each class was evaluated against each of the other proposed classes to determine which classes have the best distinction from each other.

	Make a fist	Grab the bottle	Extend the hand	Don't move
Make a fist	NA	56.39%	51.38%	64.10%
Grab the bottle	56.39%	NA	62.57%	72.99%
Extend the hand	51.38%	62.57%	NA	68.40%
Don't move	64.10%	72.99%	68.40%	NA

Table 1. Average accuracy for the binary classification model

Conclusions:

Although the response depends on each subject evaluated, there is a better response in the classification for complex movements such as grabbing the bottle than for simple movements that are executed in short periods such as extending the hand and making a fist.

The results related to the binary classification with the class maintaining anatomical position (don't move) reveal that this type of analysis can be done with good precision to detect the onset of movement through electroencephalography signals.