EEG-based discrimination of nociceptive pain levels generated by noxious laser stimulation

MSc. Rogelio Sotero Reyes Galaviz[1, 2], Dr. Luis Villaseñor Pineda[1], Dr. Camilo Valderrama[2]

[1] Biosignal Processing and Medical Computing Laboratory, Instituto Nacional de Astrofísica, Ópicta y Electrónica, Pue, México.

[2] Applied Computer Science Laboratory, University of Winnipeg, MB, Canada.

Nociception is a sensory process provoked by external stimuli that trigger physiological reactions experienced as pain. The way it is perceived becomes subjective, as it can vary depending on the emotions and behavior of each person, so analog pain scales have been developed, and new technologies are trying to find biomarkers that make these evaluations more quantitative and less subjective. In this research, we propose to detect and classify nociceptive pain caused by applying a transcutaneous laser with three different intensities using information from Electroencephalographic (EEG) signals. This study aims to be able to classify between pain and non-pain states of subjects using the biosignals from the database; it also is planned to classify between 3 levels of pain linked in an assumption to the three intensities of lasers used as noxious stimuli.

Objective

This research aims to discriminate between pain and no-pain states and detect and classify 3 different levels of pain linked to 3 different intensities of laser stimuli using EEG signals and the characteristics extracted from it, such as powerband.

Methods

The experimental protocol of the database consists of 3 core conditions (perception, motor, and autonomic). In addition, a combined condition was recorded, where each core condition was present. The four conditions were applied to each participant, and 60 applications of the laser stimulus were applied to the back of the left hand. The laser intensity varied [low=20, medium=20, high=20] in a pseudo-random way. Each stimulus application had a variable time of between 8 to 12 seconds.

The perception condition consists of the participant having to verbally state the perception of pain on a scale from 0 to 100 after each application of the laser. In the case of the motor condition, the participants had to release a button that they were pressing as quickly as possible when starting each stimulus application. In the autonomic condition, participants focused on the pain sensation without any other task, while the skin conductance response was recorded (SCR). In the combined condition, participants first had to release the button as quickly as possible and then verbally say a number from 1 to 100 in the pain rating, all while the EEG, ECG, and SCR were recorded. Subjects were instructed to keep their eyes closed during the experiments. For this research, only information on EEG signals is used.

EEG data were recorded with an electrode cap (EasyCap, Herrsching, Germany) and BrainAmp MR plus amplifiers (Brain Products, Munich, Germany) using the BrainVision Recorder software (Brain Products, Munich, Germany). The electrode montage included 65 scalp electrodes consisting of all electrodes of the International 10–20 system as well as the additional electrodes FPz, AFz, FCz, CPz, POz, Oz, Iz, AF3/4, F5/6, FC1/2/3/4/5/6, FT7/8/9/10, C1/2/5/6, CP1/2/3/4/5/6, P1/2/5/6, TP7/8/9/10, and PO3/4/7/8/9/10. Two additional electrodes were fixed below the outer canthus of each eye. During the recording, the EEG was referenced to the FCz electrode, grounded at AFz, sampled at 1000 Hz, highpass filtered at 0.015 Hz, and low-pass filtered at 250 Hz.

Results

Thirty one subjects have been classified using the band power feature of the EEG signals recorded. They show that it is possible to detect and quantify between pain and no pain states with an accuracy of more than 70% as an average of all the subjects. But not into 3 different levels of pain, with an accuracy of less than 40% in all the subjects. Due to this, another binary classification was tested but using different tags. The first tags were related to the type of stimulus applied (intensities low, high and medium of the laser). The second tags were related to the time of exposure to the stimulus. With a binary classification, accuracies with intensity tags were having a 55%. With time tags, the accuracies increased to 80% in most of the subjects.

Conclusions

Analyzing signals from 31 subjects, it is possible to detect between 2 levels of pain (high and low) by using power bands and labelling them with respect to the time of exposure to the stimulus and not the intensity of the stimulus. This may be because the reaction to pain is so subjective and variant in the same subject, that the same stimulus can be experienced in different ways.

Also, it is possible to detect between pain and non-pain states because the stimulus is so intrusive that it generates an on-off switch effect in the brain signal. On the other hand, when trying to classify 3 intensities of pain, the ‘average’ pain, so to speak, is confused with high or low signals, which makes the classifier quite unsuccessful, because the variations are very subtle between brain signals and exposure times to the stimulus. When doing a time-frequency analysis of this, it appears that the greater the level of pain, the finer and more focused the alpha band at approximately 10Hz.

At the moment a larger classification is being made using the time-frequency fingerprints. Due to the large memory size of the database, deep learning models were used with the help of the University of Winnipeg. It is also believed that the value lies in finding an obvious pain index, which may be able to tell when this phenomenon exists. It is important to note that this work is still in progress.