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CENTRO DE INFORMÁTICA E SISTEMAS DA UNIVERSIDADE DE COIMBRA

EEG study of sympathetic reactions in adverse situations

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INTRODUCTION

The ability to receive, interpret and react to visual stimuli is referred to as visual perception, and involves the lateral geniculate nucleus of the thalamus and the primary visual cortex [1].

Following the initial processing, the visual data is sent to several extrastriate cortical regions found in the brain's temporal and parietal lobes. These regions enhance higher-order visual perception and cognitive processes by integrating and analysing the visual data [1].

Empathy can be described as the change in emotional state or perspective, brought about by contemplating a certain situation. The main neural components involved in empathy are the Anterior Insula and the Anterior Cingulate Cortex [3] [4].

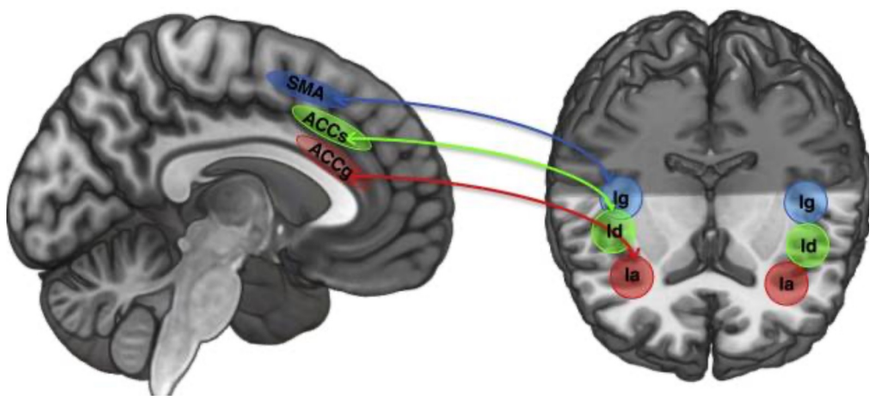


Figure 1. Connectivity between the insula and cingulate cortex's cytoarchiectonic subregions: supplementary motor area (**SMA**), sulcal section of the anterior cingulate cortex (**ACCs**), gyral portion (**ACCg**), agranular anterior insula (**Ia**), dysgranular mid insula (**Id**), and granular posterior insula (**Ig**) [2].

Researchers have increasing interest in virtual reality (VR), which is becoming more common in the scientific and medical domains. VR offers new means of presenting emotionally complex and relevant stimuli in a genuine and highly controlled manner. It has been demonstrated that VR can stimulate the brain's threat-processing system [5].

STATE OF THE ART

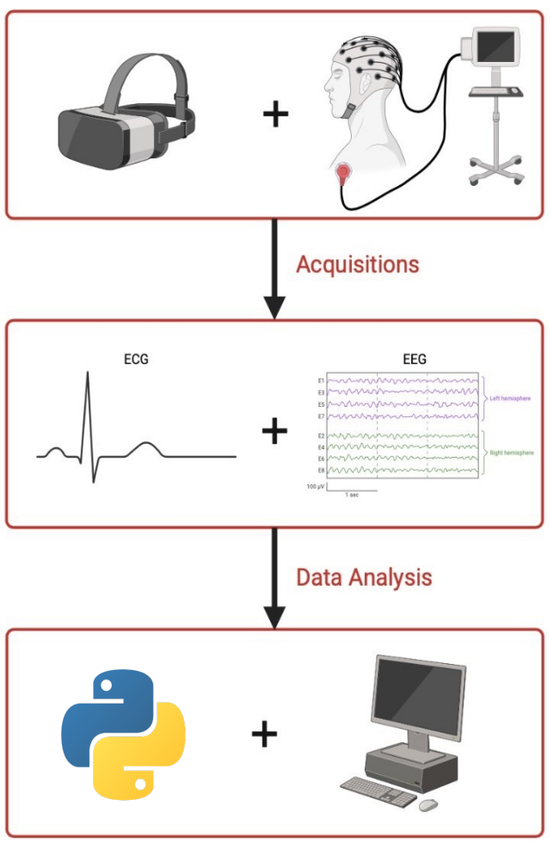
There are some studies that had explored the brain regions that activate in sympathetic reactions in adverse situations. Almost all these studies to identify the area of the brain that activates using functional magnetic resonance imaging (fMRI) or EEG. The advantages of using EEG instead of fMRI is that, unlike in fMRI studies, which provide good spatial resolution, EEG allows good temporal resolution to discern the temporal sequence of activated brain regions.

Relevant Brain Areas Involved in Empathy:

Anterior insula, anterior cingulate cortex, amygdala, prefrontal cortex, periaqueductal gray, posterior medial hypothalamus, primary visual cortex, bilateral extrastriate body area and bilateral cuneus.

GOALS AND ACCOMPLISHED WORK

The main goal is to investigate the activation patterns of distinct brain regions associated with sympathetic responses during adverse situations. Specifically, we aim to identify the specific brain areas that become activated as well as the connectivity between these areas and its temporal sequence.



1. Development of a VR Scenario

The initial phase of the project involved the creation of a VR video. This video simulates an adverse situation, that will be presented to a "*virtual*" individual.

2. Analysis of Cortical-Brain Activity

The video was presented to 12 healthy candidates, where an assessment of the evoked cortical-brain activity was conducted using EEG and ECG.

3. Data Analysis

The ECG and EEG data were pre-processed (filtered and ICA), followed by spectral feature extraction. Preliminary statistical analyses were obtained.

Figure 2. The methodology employed in the project encompasses several distinct stages. It commences with the Development of the VR Video, proceeds to the acquisition of EEG and ECG data, and culminates in the data analysis phase conducted using the Python programming language (Created with BioRender).

After the approval of the ethics committee, a group of healthy participants followed the testing protocol. Some of them showed empathy towards the virtual entity, which led to promising results for the study.

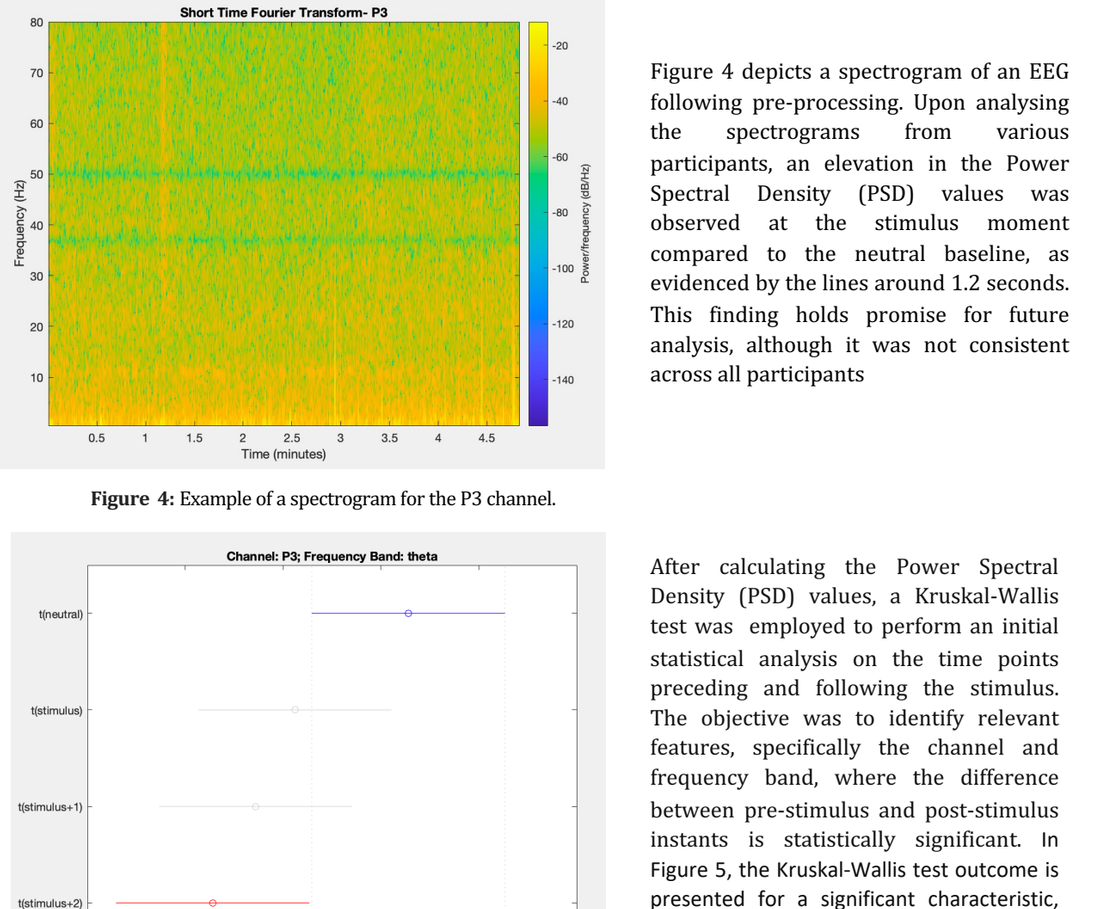


Figure 3. Example of a participant (left) and a frame of the developed VR video (right).

RESULTS

Following the completion of the pre-processing stage, which involved filtering, noise reduction, and artifact removal via the elimination of components using Independent Component Analysis (ICA), a spectrogram analysis was conducted. Power Spectral Density (PSD) values were computed as part of the analytical process and evaluated using the Short-Time Fourier Transform (STFT) with a window size of 0.5 seconds.

Figure 4: Example of a spectrogram for the P3 channel.

Figure 4 depicts a spectrogram of an EEG following pre-processing. Upon analysing the spectrograms from various participants, an elevation in the Power Spectral Density (PSD) values was observed at the stimulus moment compared to the neutral baseline, as evidenced by the lines around 1.2 seconds. This finding holds promise for future analysis, although it was not consistent across all participants

Figure 5: Multiple comparison test for the feature channel: P3, band: theta.

After calculating the Power Spectral Density (PSD) values, a Kruskal-Wallis test was employed to perform an initial statistical analysis on the time points preceding and following the stimulus. The objective was to identify relevant features, specifically the channel and frequency band, where the difference between pre-stimulus and post-stimulus instants is statistically significant. In Figure 5, the Kruskal-Wallis test outcome is presented for a significant characteristic, specifically, the left parietal lobe.

Future work

- Increase the number of data acquisitions to enhance statistical significance.
- Implement time-space pattern recognition techniques and conduct additional statistical analyses on the extracted features.
- Investigate cortical connectivity patterns and determine the sequential activation sequence of brain regions over time.
- Conduct a comparative analysis of obtained results with findings from prior studies.

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