# Developing a System for Graphical Analysis of Brainwaves During Media Consumption

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## Abstract

This paper describes a data visualization artifact, designed to capture, analyze and generate an imprint of the user's brainwaves from electroencephalographic readings in real-time during the consumption of media content. Such waves, naturally emitted by the human brain, will be mapped, categorized, stored and graphically printed within the scope of the Design Science Research methodology. The generated Brain Computer Interface can be used as an input in various systems, such as neuromarketing and media recommendation. Given that experience and perception of media consumption is variable and, therefore, subjective among individuals, this research aims to obtain relevant data in the context of studying multimedia interaction and development.

***Keywords:*** BCI, data visualization, DSR, EEG, Eye-Tracking

## 1 Problem Characterization and Motivations

The usage of electroencephalography (EEG) in Brain Computer Interfaces (BCI) seems promising in the field of audiovisual content production and consumption. Feedback can be collected in pervasive and immediate ways, which removes the layer of subjectivity in a user's experience evaluation process. Noticing that, a tool for graphic visualization and interpretation of brainwaves and their patterns in real-time was developed. It is briefly described in this expanded abstract. As it emphasizes the observation of media consumption, it utilizes the Design Science Research methodology.

Neural signals have a complex and interdependent nature, being simultaneously emitted on different parts of the brain. Moreover, it is notable that an uncomfortable device could impair the fruition of media. The Emotiv Insight 2.0 EEG headset was used as a means of gathering and processing the data utilized in this study. The selected device is based on five channels of EEG reading and is capable of outputting raw data about mental commands, performance metrics of the obtained signals and detection of facial expressions. It is the only widely available option capable of reading signals from all cortical lobes of the human brain, which enables its usage for scientific research. Despite the equipment's capabilities, it was not designed or intended for the diagnosis or treatment of medical conditions.

Similar to most products manufactured by Emotiv, the Insight headset utilizes the "Cortex API". This application programming interface, alongside the "Emotiv Launcher" application, enables the interpretation of EEG signals obtained through the chosen device. In order to collect and display the data read by the headset in real-time, a software was developed using Python programming language. It consumes the data obtained by the API and facilitates gathering, storing, categorizing and analyzing the brain waves of individuals during interaction with media.

The artifact presented on this paper uses the readings from all electrodes available on the selected EEG headset. These are placed on the AF3, AF4, T7, T8 and Pz positions on the international 10-20 scalp mapping system for EEG. Through the Python application, the states of the Alpha, Beta, Gamma and Theta waves are continuously stored while media content is exposed to the users. This enables the quantifying of the actuation forces of neural waves in the specified areas of the human scalp. Neural feedback in this areas relate to the user's attention, relaxation, focus and emotional synchronism to what's shown on screen.

## 2 Objectives and Contributions

Given the context of this project, the main objectives for the development of the artifact were: 1 - to build a suitable

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test environment in which the brainwave data is properly collected, recorded, mapped and visualized synchronously with the fruition of media; 2 - to use a non-invasive, easy-to-use, relatively comfortable and affordable equipment; and 3 - to find a way to link patterns found in the obtained data. In other words, regular disturbances in results which can be related to focus or reaction to specific elements on the shown media.

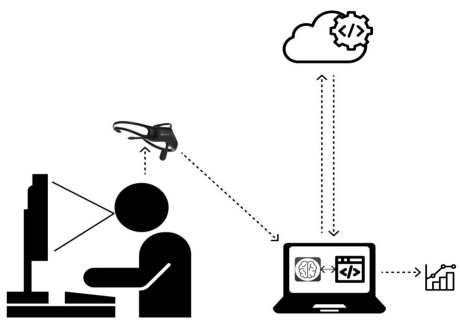

**Figure 1.** Diagram exemplifying the developed artifact's pipeline

Figure 1 shows a model representing the produced artifact, which complies with the set objectives. It can be defined as a system which exposes the user to a chosen audiovisual content, whilst wearing an EEG headset. Collected data is sent in real-time to a cloud server in constant communication with the API, which processes raw EEG data. Furthermore, the registered data is immediately used to plot a dynamically constructed chart. It displays the relation between band power and the time elapsed since the beginning of the recordings in seconds. Band powers, relative to the theta(4-8 Hz), alpha(8-12 Hz), low beta(12-16 Hz), high beta(16-5 Hz) and gamma(25-45 Hz) frequency bands, are measured in $\mu V^2/Hz$. Processed data is stored during the readings and exported as a CSV file once the recording routine is finished. This feature enables the usage of other data processing tools, which can be found handy in further search and interpretation of brain activity patterns.

Eye gaze mapping was chosen as the missing link between the consumed content and the data gathered via EEG readings. In order to track the users' ocular movements towards the shown content, the free webcam-based platform "Gaze Recorder" was used. After each experiment, the accessory application generated a heat map. It shows approximately where on the screen the user was looking at during the chosen period of time. The synchronization of the EEG results and the generated eye tracking heat maps can provide clues on what exactly was influencing the brainwave variations and patterns.

## 3 Related Works

The described artifact is a new iteration of the systems presented by Tavares et al.[7] and Becker et al.[2], as a result of the natural progress of the research at Laboratório de Interação e Multimídia - UFPB. Close relation to the developed artifact can be found on another paper by the same laboratory. It describes the potential of BCIs for on-demand video recommendations[1].

In addition to that, papers regarding the association of EEG brainwaves and eye tracking devices were analyzed for the production of this artifact. Lu et al.[5] combined data extracted from both EEG and eye tracking devices. It was found that the usage of the fuzzy integral as a strategy for emotion recognition shows an accuracy of 87,59 percent. Lopez-Gil et al.[6] show another application based on the usage of EEG, eye tracking, and biometric signals for emotion recognition. Works that disclosed the use of eye tracking data for the implementation of recommendation systems were also analyzed. Xu et al.[9] use the user's attention time to each item in a document, image, and video platform to recommend new content. Usage of eye tracking can also be seen studies of usability and in neuromarketing, as a tool for predicting user's consumption and product usage patterns. By analyzing these studies from other authors, it is acknowledged that an eye tracking device could help to understand what exactly is influencing the brain waves results. Therefore, infrared eye tracking camera technology is expected to be used in future works, in order to supplement the analysis of EEG responses.

## 4 Results

The resulting model employs a python script, adapted from the cortex API examples available on its GitHub page[4]. It runs until a set target amount of packets of the chosen data stream is sent by the EEG headset. From the available data streams, "Band Power" information was used in this artifact's current iteration. As a secondary routine, a CSV file is built by registering each line of obtained information. The provided data is consumed by a chart in real-time, which displays the band powers over the number of already received data packets.

In addition to the recording script, another one, focused exclusively on processing the data stored in the CSV file into charts was written. It enables for the plotting of charts with information about any combination of the available EEG channels and bandwidths. Readings of the Theta, Alpha, Low Beta, High Beta and Gamma frequencies on the AF3, AF4, T7, T8 and Pz channels are available. This plotting script does not receive any external inputs. Consequently, the input of parameters such as which channels and bandwidths to plot, name and path of the source CSV files shall be provided through direct alterations in the code.

In this application, the sheer amount of data packets received is used instead of the elapsed time since the beginning of the recording. It both controls the script's stopping criteria and tracks the order of the readings. This choice is justified by the ease and weightlessness of converting the data into manipulable objects and plotting the results. The conversion of the amount of data packets received to time in seconds is a simple process and can be done after the data manipulation, without further drawbacks. It can be achieved through the usage of information regarding the sampling rate, available at the cortex API gitbook[3]. The following figures illustrate some features and byproducts of the produced artifact, allowing a further expansion on its inner workings.

While in run time, the script waits until it receives the desired name for the resulting files as input. Following that, the due API authentication process is executed, immediately triggering the start of the recordings. It continues until the desired amount of data packets, defined manually in the code, is received by the application. It is shown in real-time as it's concurrently plotted and stored in a CSV file. Each row of a CSV file generated by the artifact represents the data from a data packet, containing a itr value. This variable is used to keep track of the amount of data packets already received by the application. Beyond that, the rows have 25 values relative to the band power readings of each frequency band in each EEG channel.

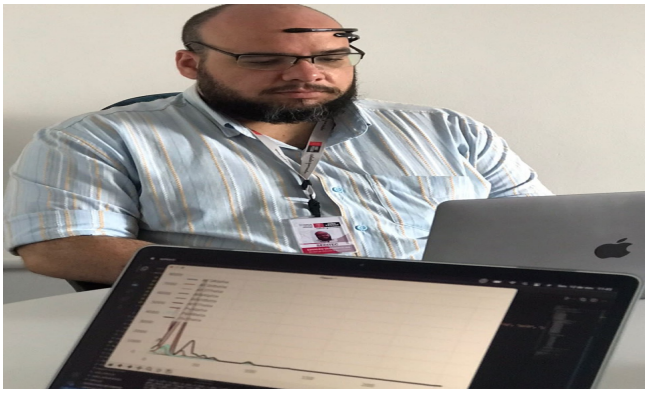

**Figure 2.** Photo of the artifact in use taken during one of the tests.

To validate the proposed model, experiments were carried out in a lab environment as shown in figure 2, with 15 male users of ages between 18 and 55 years old. Disposing of the time used to arrange the Emotiv Insight's electrodes on the user's scalp through the tool provided by the manufacturer, each interaction lasted for about four minutes. In this period of time, static images were available for the viewing and judgment of the spectators. In a latter iteration of the experiments, the trailer of a thriller film was shown, aiming to observe the users' reactions to moving pictures in an atmosphere of higher tension. The users' five brainwaves were observed in real-time and stored in a database for later comparison. The Alpha, Beta and Theta waves were graphically exposed, in the F3, F4 and T7 positions in the 10-20 EEG system, located in order to read waves in the frontal brain lobe.

Although the same images were presented to the experiment participants, some discrepancy between stored results was noticed. Through interviewing the spectators, it was possible to verify different perspectives on the same subject. The results can be justified by the difference in each user's focus during the fruition of media consumption. According to reports following test sessions, some users tried to focus on specific aspects of the shown media pieces. In contrast, others tried to correlate the content on the screen with personal past experiences.

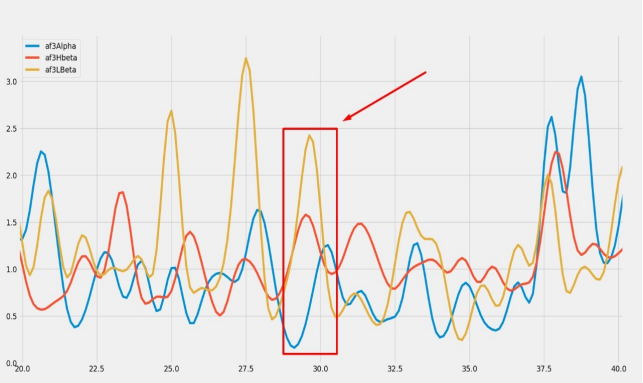


**Figure 3.** Example of a chart made with the plotting script

Figure 3 consists of an example of a chart that can be produced with the plotting script. Development was centered on the flexibility of choice regarding which data processing tools and techniques will be applied. This also applies to which EEG channels and brainwaves will be processed and analyzed. The chart in figure 3 displays processed information about the Alpha, Low Beta and High Beta band power readings in the AF3 channel during a test recording. It was enhanced to highlight an area of interest around the 29 seconds mark. The area corresponds to a moment of sudden tension that occurs at approximately 29 seconds, in the film trailer screened in one of the test iterations.

To generate a chart with the plotting script, the CSV file with the recorded brainwave readings is used as an input. It provides the information that is gathered in a dataframe[8] object, used to filter and process the data. In Figure 3's chart, all data regarding the readings of any other available EEG channel and brain regions, besides the selected ones, was filtered. Following that, the remaining data was used to compute the ratio between the band power readings of each analyzed brainwave in each analyzed EEG channel, as well as their corresponding mean value relative to the entire recording. Finally, the processed data values were used to

generate the chart. It displays the value of the relative band power of the selected brainwaves and EEG channels over time. This technique facilitates the identification of spikes and plunges in charts with different frequency bands and channels. These gravitate towards having distinct values and amplitudes. This tendency can potentially derange the scale of the values shown in the chart, impairing their interpretation.

Analyzing the highlighted area in figure 3's chart, it's notable that a spike in the Low Beta frequency band and a plunge in the Alpha frequency band occurred roughly at the same time. Given the context of the tests carried out, this phenomena could then be interpreted as a fright pattern that emerged in response to a stimulus, which in this case is the sudden intense fright that happens in the trailer of a horror movie. The human brain proceeds to immediately normalize the harmony between the observed brainwaves. Said event refers to the natural process of rationalization of fear, as the user realizes the imminent threat is not continuous or real. This conclusion exemplifies how this artifact can be used to empower emotion analysis.

The presented artifact is still in the testing stages. However, it is possible to ratify the potential that lies within applying Brain Computer Interfaces to aid in the comprehension of fruition in the consumption of audiovisual content. Overlapping the results of Brainwave monitoring with the timeline of the observed content enables the perception of changes in the spectator's neural behavior. These alterations can be motivated by what is seen on screen. Such aspects of fruition are normally ignored, omitted or even unknown by the viewer itself while exposed to the piece of media. Considering these subjective and individual nuances can contribute to a personalized content consumption experience. This is justified by the depth of the behavioral analysis of the user during an interaction.

## 5 Conclusion

This article described an EEG-based BCI for reading, processing, storing and retrieving data about the behavior of a user's neural waves during audiovisual fruition. It contributes to the accurate obtaining of information about interactions with media work pieces. To carry out the research, a market-available EEG device was used to gather brain wave signals. Tests were conducted in a lab environment utilizing the gadget paired with the developed python program, with its results being graphically displayed in real-time.

The presented BCI is an evolution of the system already employed at the LIM- UFPB lab. Thus, it enables the use of powerful data processing tools such as data frames, and techniques e.g., the comparison with the average band power value described in the results section and so forth.

Further expansion of the research include defining a pattern of heuristics to contemplate emotional involvement. In other words, how much the individual liked or disliked the whole or fragments of work pieces, through the analysis of neural waves. In addition, it is necessary to consolidate the system used for the graphic analysis of the waves read, since the tests were carried out with a small number of participants. The coupling of accessory technologies shows promising in increasing the accuracy in the representation of the user's emotional state during the moment of interaction. For such objective, monitoring the user's eye in relation to the screen or the capture of facial expressions during media fruition are seen as high contenders.

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