Classification of cognitive states of attention and relaxation using supervised learning algorithms

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Abstract **- The study of cognitive states has attracted the attention of artificial intelligence researchers searching for mechanisms to enable brain-computer communication. With the advent of portable brain-computer interfaces, it is now possible to study human behaviors towards using cognitive states in gaming environments. NeuroSky's Mindset is a device with the operating principle of enabling portable EGG sensors to allow the reading of brain frequencies in real time. We believe that this type of device may be a very adaptable option to videogames to create new experiences and allow a new control mechanism. This interaction would be easy and natural and based less on motion and physical effort. This paper reports an assessment of the Mindset reader, particularly in relation to classifying the cognitive states of attention and relaxation, behaviors associated to the brain waves read by the device, using supervised learning algorithms. The aim is to estimate behaviors using human brain frequencies as inputs.**

I.INTRODUCTION

Attention processes are typically related to the user's psychology [8] since these refer to cognitive processes reflected on the behaviour of individuals. Traditional approaches to study attention include the determination of the relationships between the functioning of the nervous system and different processes comprising sensory, motor and cognitive. The study of the cognitive state of attention as computer input is a novel area requiring the collection of accurate data in the context this data can be applied to. Attention is read since brain activation is higher in some areas including frontal and parietal lobe. In psychological settings, however, current measurements of attention is carried out by standardized tests that are necessarily subjective as the person can express something different from what they are experiencing.

This paper reports on the use NeuroSky's Mindset device, a brain computer interface capable of reading neural activity based on the frontal lobe brain using electroencephalogram (EEG) principles. Direct readings of brain electrical frequencies using devices such as the Mindset might be an objective way to estimate the individual's attention. The Mindset already generates two measurements with its proprietary software but we decided to work with raw measurements to analyze and determine whether these states are detectable using artificial intelligence classifiers. Previous works [1,2,3,4,5,6] have shown that the classification of cognitive states is possible [7]. Therefore, it is important to establish whether the readings of the full-wave spectrum allow the reading of brain activations in association with expected behaviors. An advantage of using raw readings is that it is possible to analyze user's records when exposed to different types of stimuli, to determine whether the readings provided can be mapped out to human cognitive states.

II. METHODOLOGY

The study reported on this paper followed a methodology shown on Fig 1. This methodology consisted of showing different stimuli to 20 undergraduate students whose ages ranged between 18 and 28. This allowed the exploration of different tasks while capturing neural activation via the Mindset device. The six waves considered on this study are Low Beta, Medium Beta, High Beta, Alpha, Delta and Gama. The resulting data was classified using supervised learning algorithms including KNN, LDA, C 4.5 and Naïve Bayes, The results obtained showed promising prospective of classification with accuracy percentages of above 80%.

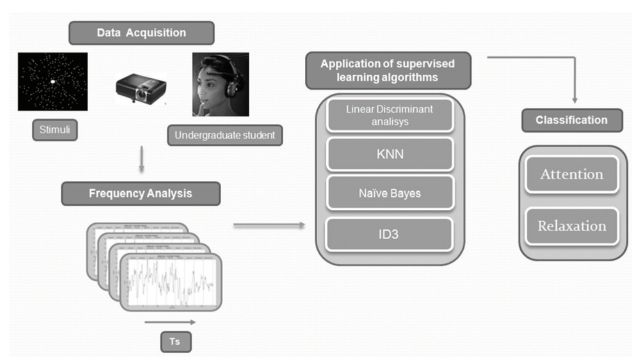

Fig. 1. General diagram of the methodology.

Matlab was used to connect the Mindset device to the computer as well as for recording, filtering and organization of the data. The Neurosky Lab library was employed by Matlab and amended for the purposes of this research. Visual stimuli were generated using Psychtoolbox 3.0.

A. Frequency analysis

The procedure used after data acquisition was to transmit the raw signal through a band-pass filter for each type of wave (delta (0.1 to 3 Hz), theta (4-7 Hz), alpha (8-12 Hz), low beta (12-15 Hz), mid beta (16-20 Hz) and high beta (21-30Hz). It is worth mentioning that the complete frequency spectrum (all six waves) is present at all times even though one brainwave is predominant at a given time. The predominant wave is the wave picked up and recorded by the MindSet device at one given time indicating the dominant wavelength for the current second. Ergo, the detected real-time signal is filtered from each range of waves and an index is obtained for each wave even though there is only one predominant wave.

After that, the data was pre-processed through standardization since it clearly showed changes in the signal making it almost imperceptible. The standardization consisted of using the gradients of the plotted data based on the fragments of time-series for each condition that was part of the stimulus, using the least squares method, see Fig 2.

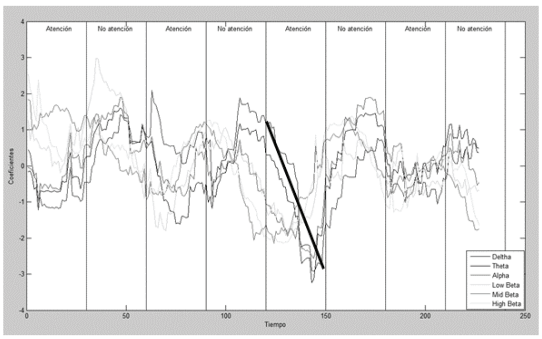

Fig. 2. Wavelength per condition for each wavelength approached him a line at which the gradient was calculated.

A database with the gradients for each of the experiments was created and the following supervised learning algorithms were applied: Fisher Linear Discriminant Analysis, ID3, Naïve Bayes, KNN and the latter for k = 1, k = 5 and k = 10 neighbors. These methods allowed for the classification of the data and also the evaluation of the type of classifier that yielded better results. The method of performance evaluation chosen was leave one-out.

B. Experiments

We chose to present 20 subjects with different visual stimuli aimed at inciting the reaction into the cognitive states that we sought to identify. Among the stimuli, we replicated a classic experiment of visual stimulus motion [1]. Other experiments included performing tasks such as arithmetic, logic, optical illusions, etc., reading, listening, interacting with a video game and opening and closing eyes. A pretest was carried out by the subjects before individual stimuli. Other data collected comprised hours slept the night before, age, gender, use of glasses, drinking alcohol, coffee or cola previous and current day or smoking and handedness.

1) Open and Close Eyes

We selected this experiment because there are basic reactions in the subject in relation to attention. During the experiment the subject was sitting in a chair and asked to relax and keep the eyes closed for 30 seconds after which a signal was given (touching the arm) to indicate to open the eyes and observe a letter A in front of him (to fix the attention on a single point and avoid distractions) for 30 seconds. This exercise was repeated 3 times for which the duration of the experiment was 3 minutes.

2) Performance during the interaction with a video game

During this experiment a game of skill and dexterity was selected with two conditions (playing and not playing) to observe changes in the user´s recorded waves. This experiment was carried out with the video game Guitar Hero 3 on its computer version with the song "Sunshine of Your Love" at the level that each person felt capable of performing more comfortably, see Fig 3.

Fig.3. Way to play the video game Guitar Hero III for PC

It is noteworthy to mention subjects were allowed to play from 1 to 4 songs (other than the track used for testing) to get used to playing using the keyboard. There were 4 runs for each subject with the same song. The subject played the video game for 30 seconds at the end of which a visual signal indicated the user to stop playing and to merely watch the monitor for 30 seconds. Both conditions, playing and resting, were presented alternatively until the song finished after 4.22 min.

3) Display Images

This experiment showed a series of 16 images to challenge subjects to find differences in a pair of images, word search, search of a subject in a image, optical illusions, relaxation landscapes, logical operations, among others. Each image was presented for 30 seconds allowing for a 5 seconds rest between the displays. The rest showed a black screen. The duration of the stimulus was 630segs by a single run per subject. This experiment aimed to capture the subject's reaction to different types of actions that may cause marked response (as showing a man a woman in a bikini) or relaxation (e.g. displaying a landscape).

4) Büchel[1] playback experiment

This stimulus consisted in focusing the subject's visual attention to the movement of points over a black screen. Its duration was 4 minutes 48 seconds (32 sec per image) and each test subject was presented with 4 different conditions:

- Stationary Condition (S): 250 Points stationary white points on a black screen with a white dot fixed in the center.
- No attention condition (N): 250 White points that move in and out on a black screen with a white dot fixed at the center.
- Fixation condition (F): 1 fixed white point in the center.
- Attention condition (A): 250 White points that move in and out on a black screen with a fixed point to the center where the participant must attend to the number of times that points towards and away from the central point.

Each condition was shown 4 times following 2 different orders, the first two runs were in the order: F A F N F A F N S and the last 2 in the order: F N F A F N F A S.

III. RESULTS

1) Open and Close Eyes

This test was applied to 20 individuals who formed a database of 120 records. For each individual 6 tuples were obtained. Table 1 show the accuracy achieved in the classification with database of open and close eyes:

TABLE 1. CLASSIFICATION ACCURACY IN OPEN AND CLOSE EYES TEST

LDA Fisher	**50%**
KNN k=1	**92.50%**
KNN k=5	**90.83%**
KNN k=10	**90.83%**
Naïve Bayes	**82.50%**
C4.5	**86.67%**

2) Performance during the interaction with a video game

The database was formed with 648 records of 18 individuals who took the test, 36 records were obtained for each subject. Table 2 shows the results of classification accuracy during the interaction with a video game.

TABLE 2. CLASSIFICATION ACCURACY IN GAMING TEST

LDA Fisher	**55.56%**
KNN k=1	**80.25%**
KNN k=5	**84.26%**
KNN k=10	**82.10%**
naïve Bayes	**67.59%**
C4.5	**57.72%**

3) *Display Images*

We obtained 16 records per subject, applying the test to 10 subjects a database of 160 records was obtained. Table 3 shows the accuracy achieved in the classification with database of display images test.

TABLE 3. CLASSIFICATION ACCURACY IN DISPLAY IMAGES TEST

LDA Fisher	**25%**
KNN k=1	**18.13%**
KNN k=5	**27.50%**
KNN k=10	**28.75%**
Naïve Bayes	**14.38%**
C4.5	**25%**

4) Büchel[1] playback experiment

The database consisted of 360 records, 36 tuples for each subject using the test for 10 subjects. The accuracy achieved by classifying this data from exposure of tests subjects to playback Büchel et al. [1] stimuli can be seen on Table 4:

TABLE 4. CLASSIFICATION ACCURACY IN BÜCHEL[1] PLAYBACK TEST

LDA Fisher	**44.44%**
KNN k=1	**42.78%**
KNN k=5	**50.28%**
KNN k=10	**51.94%**
Naïve Bayes	**36.11%**
C4.5	**43.61%**

IV. CONCLUSIONS

One of the experiments that yielded better results based on classification percentages was the performance during the game. This last result confirms that the intended market for the Mindset device does provide the sort of data needed to classify cognitive behaviors using brainwaves. Having evaluated the different classifiers in the various tests made to the subject, the classifier that performed best using as criteria the percentage of accuracy achieved by classifying, was KNN k = 10, indicating that k = 10 reduces the noise effect in the classification being based on a greater number of items to be achieved. This means that KNN was the classifier that best suited this kind of data. On the approach regarding gradient representation, agreed between each of the frequencies associated with each cognitive status, the physiological brand has found that the gradients are positive and to an extent the gradient value is higher, better expressing their individual frequencies tendency to be the predominant cognitive state.

Based on the experiments and classification results of these cognitive states, we concluded it is possible to determine detectable brain activity in the frontal lobe with high accuracy (84.26%) using the Mindset device. Furthermore, because the video game stimulus requires higher sensory processing and concentration, video games are ideal for this using brain activity as input using this type of device. Future works involves a thorough analysis of appropriate stimuli such as the exploration of video games with an important sensory processing requirement. Currently, we are continuing with this project working with different types of videogames like survival horror, arcade, etc. Another possibility for future work involves the use of other gradient approaches employing discretization methods such as SAX. Finally, a variation of this work would involve extra sensors such as video cameras to capture the gestures, eye-trackers for visual attention or bracelet to measure blood flow and electro dermal activity (EDA). This is based on the belief that having more variables would give a more complete result of the current vognitive state the subject.

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