Usability Evaluation of Brain Computer Interfaces: Analysis of Methods and Tools

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***Abstract*—Usability includes concepts such as satisfaction, efficiency and effectiveness. This may be partly the result of functionality, but they are mainly defined by the user's interaction with the system. The Brain-Computer Interface- BCI provides a direct communication path between the brain and the external world by translating signals from brain activities into codes or commands. The purpose of usability of BCI is that the interfaces can be understood, learned, used and be attractive to user, under specific conditions of use. For usability evaluation of BCI different methods (Questionnaires, Interviews, neurophysiological measures) and tools (VAS, QUIS, SUS, electroencephalography - EEG, functional near-infrared spectroscopy - fNIRS), magnetic encephalography - MEG) have been proposed. The evaluations are generally based on traditional methods (Questionnaires or Interviews), obtaining subjective answers without the certainty of the precision. In this paper an analysis of the usability evaluation methods of the BCI is presented.**

***Index Terms*- Usability, Brain Computer Interface , Methods, Evaluation.**

I. Introduction

Usability has been described by several definitions [1] and discussed by academic researchers and industry professionals for a long time. These previous studies proposed that the key point of usability is that users can use a particular technology artifact with relative ease according to a specific context of use. Nowadays, Software systems are evaluated with different usability methods (interviews, questionnaires, observational analysis, neurophysiological measurements (electroencephalography - EEG, functional near-infrared spectroscopy -fNIRS, magnetic encephalography - MEG).

The Brain Computer Interfaces (BCI) are designed to help in providing means of communication, it is an assistive technology that supports activities. The main domains of the BCI application are: Medical, Entertainment and Art, being mostly occupied in the medical area. For the evaluation of usability in this type of interface, BCI have introduced different methods (Questionnaires, Interviews, neurophysiological measurements) and tools (NASA TLX, SUS, QUEST), the most busy method for the evaluation of usability in BCI are the questionnaires.

In this paper we presents an analysis of the evaluation methods traditionally used on usability evaluation of the BCI, showing the advantages and disadvantages of each method. The second section presents the definition and importance of usability, its main dimensions, its methods and evaluation tools. The third section explains the difference of HCI and BCI, the fourt one presents a classification of works with BCI applications and algorithms used for its development, also the main application domains that were detected. The fifth section describes the evaluations of the usability of BCI, showing at what moment the evaluation methods are applied and the problems or disadvantages of each evaluation method and also a discussion. Finally in the sixth section a conclusion and future works is presented.

II. Usability evaluation

Usability applies to all aspects of a program, system or device with which a human being could interact, including installation and maintenance procedures. It is very rare to find a computer function that does not really have user interface components. Even an installation to transfer data between two computers will usually include an interface to solve problems and increase the ease of use. Usability is part of the broader term "user experience-Ux" and refers to the ease of access and/or use of a product or website [1]. A design is not usable or unusable; its characteristics, together with the context of the user (what the user wants to do with it and the user's environment), determine its level of usability. The official definition of ease of use of the ISO 9241-11 standard is: "the extent to which a product can be used by specific users to achieve specific objectives with efficiency, efficiency and satisfaction in a context of specific use" [1]. The Usability arises from the acceptance of the system, which is basically the question of whether the system is good enough to satisfy all the needs and requirements of the users. Jakob Nielsen has been a leading figure in the usability field since the 1980s, highlights the multidimensional nature of usability. To be usable, a product or service must consider these five basic dimensions/categories: Learning ability, Efficiency, Memorability, Error tolerance and prevention y Satisfaction [2]. There are many measures for evaluating usability that have been addressed, among them: "Easy to use", "Learning ability", "Consistency", "Frustration", "Task speed", "Precision", etc. But it can be stipulated that the three central principles for the measurement of usability are efficiency, effectiveness and satisfaction [3]:

- `Efficiency`: The system should be efficient to use so that once the user has learned the system, a high level of productivity is possible.
- `Effectiveness`: Accuracy and integrity with which certain users achieved specific objectives in a particular environment. For that, the system should have a low error rate so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
- `Satisfaction`: The system should be pleasant to use so, the users are subjectively satisfied when using it; they like it. Satisfaction is an affective state or attitude of the user resulting from a global evaluation of the interactions produced.

A. Usability evaluation measures

There are many measures for evaluating usability that have been addressed, among them: ”Easy to use”, ”Learning ability”, ”Consistency”, ”Frustration”, ”Task speed”, ”Precision”, etc. But it can be stipulated that the three central principles for the measurement of usability are efficiency, effectiveness and satisfaction. Taking into account these principles on [4] they have been proposed a classification of usability evaluation measures in terms of efficiency, effectiveness and satisfaction, they divided the evaluation (measurement characteristics) into two main categories: subjective measures and objective measures. The subjective aspect refers mainly to the satisfaction of the user and the cognitive workload, on the one hand it encompasses satisfaction with measures of ease of use, learning capacity, usefulness, reliability, consistency, etc. and for the other part of the efficiency taking the mental demand, comfort, frustration, effort and physical demand. By contrast, the objective aspect means ”How efficient and effective is a system / product for a user to perform a task to achieve some intended objectives”, consider satisfaction with task accuracy, classification accuracy, error rate, rate of completion of tasks, etc., and part of the efficiency taking task speed, task time, processing time, selection time [4].

B. Usability evaluation methods

Current methods for assessing usability can be classified into quadrants of a plane that has an objective axis versus a subjective axis and a qualitative axis versus a quantitative axis. Objective methods are based on open and covert user responses during interaction, while subjective methods are based on the user’s expressions after the interaction. Quantitative methods use statistical analysis of collected data, while qualitative methods are interpretations of user responses by researchers [1] [5].

C. Usability evaluation tools

Usability measures can be obtained through usability evaluation tools: i) Interviews / Questionnaires and ii) Neurophysiological. Some examples of these tools are presented below [4]:

1) Interviews / Questionnaires:

- NASA-TLX is a popular technique for evaluating the mental workload that is based on a multidimensional construction. It derives a general workload based on six subscales: mental demand, physical demand, temporary demand, performance, effort and frustration;
- VAS is a method to evaluate a ”feeling”, it is usually done to evaluate the satisfaction of a system in the BCI usability studies;
- ATD-PA and QUEST 2.0 are specialized tools for evaluating assistive devices, it consist of a set of questionnaires to evaluate the match between the person and assistive technology;
- The SUS survey and the USE questionnaire are simple but effective tools to evaluate the usability of several products, the SUS survey contains a 10-item scale that provides a global view of usability and the USE questionnaire contains a 14-item scale that refers to four domains: satisfaction, ease of use, ease of learning and usefulness;
- The IBM computer usability satisfaction questionnaires also measure user satisfaction with usability, but specialize in a computer system,
- QCM is a specialized subjective evaluation tool to measure the motivations of users with respect to four motivational factors: domain congestion, fear of incompetence, challenge and interest.

2) Neurophysiological:

- Functional near-infrared spectroscopy- fNIRS. This technique measures the absorption of NIR light in blood hemoglobin with or without oxygen and provides information about functional brain activity similar to functional magnetic resonance imaging studies.
- Electromyogram- EMG. An electromyogram measures the electrical activity of muscles when they are at rest and when they are being used. Nerve conduction studies measure how efficiently and at what speed the nerves can send electrical signals.
- Functional Magnetic Resonance Imaging- IRMf. Functional magnetic resonance imaging or fMRI is a technique that allows you to obtain images of brain activity while performing a task.
- Electroencephalography-EEG. The EEG measures the electrical activity of the brain at different sites of the head, usually using electrodes placed on the scalp.

III. Human Computer Interface

The term interface is used to name the functional connection that exists between two programs, systems or devices, which provides communication at various levels, making possible an exchange of information. The interfaces have been evolving, from the CMD command line interface in 1970, to the natural user interfaces that have been developed in these times. According to their evolution, they can be classified as:

- Command Line Interface (Command-Line Interface, CLI): Alphanumeric interfaces (command interpreters) that only present text.
- Graphical User Interface (GUI): Allows to communicate with the computer in a fast and intuitive way, graphically representing the control and measurement elements.
- Natural User Interface (NUI): They can be tactile, graphically representing a ”control panel” on a touch-sensitive screen that allows you to interact with the finger in a similar way to if a physical control is activated; they can work through speech recognition, such as Siri; or through body movements, as is the case with Kinect.

The Human-Computer Interface - HCI deals with the methods by which computers and their users communicate. It is the process of designing interface software so that computers are pleasant, easy to use and do what people want them to do. Dealing with HCI requires the study of not only the hardware of the computer, but that of the human side also. Therefore attention must be paid to human psychology and physiology. This is because to build a better two-way communication, one must know the capabilities and limitation of both sides. In the figure 1 the architecture of HCI is shown and a comparison with the architecture of a BCI is made.

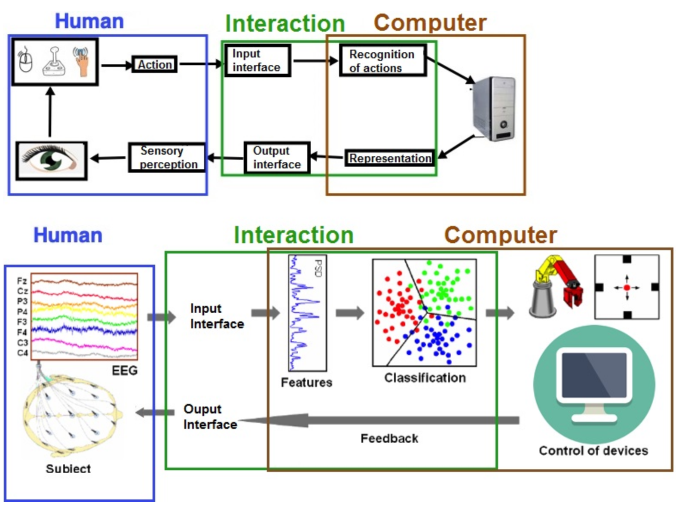

Fig. 1. Architecture Interface G U - Brain Computer Interface

The architecture of any HCI, as its name says it can be divided into 3 important parts. The first part is the cognitive functions executed when the human being receives, interprets and stores information, at the moment of sensory perception, then an action is executed according to the previous perception. The second part is the interaction, when the action performed by the user is sent to an input interface, recognition of the action is made, the representation and ending with the sending to the output interface, to start again the cycle with the perception. The third part, is the recognition of the actions by the computer and the subsequently representation, the computer is in charge of interpreting the user’s cognitive functions and executing the actions thus giving the user feedback to continue with the cycle.

In the BCI, the main parts of the HCI architecture do not change, but there are some differences. The human phase is now developed by the brain and no longer performs any muscular action, the human brain is where all cognitive functions take place. It is where a human being receives, interprets and stores information. The information can be processed by the sensory organs and sent to the brain faster. The Interaction phase now receives the action but by means of the electroencephalographic signals and for the recognition of the actions an extraction of characteristics and a classification is carried out, all this by means of statistical methods.

IV. Brain Computer Interface

At the Brain Computer Interfaces (BCIs), th exchange of information takes place between the electrical activity of the brain and the device to be controlled. BCIs provide their users with channels of communication and control that are not dependent on the normal output channels of the brain of peripheral nerves and muscles. It is a control and / or communication system in which the commands and messages of the user do not depend on muscular control. The information is not transmitted directly from the nerves and muscles, and muscle activity is not necessary for the production of the signal that is needed to transmit the message [6]. BCI can be developed using a variety of different types of neurological signals, such as functional near-infrared spectroscopy (fNIRS), magnetic encephalography (MEG), or functional magnetic resonance imaging (fMRI). However, one of the most used methods to measure the neurological activity used in BCI is the electroencephalogram (EEG).

The EEG measures the electrical activity of the brain at different sites of the head, usually using electrodes placed on the scalp. Its main advantages over other recording techniques are its high temporal resolution and the fact that it can be recorded non-invasively (that is, without the need for surgery). Due to their relatively low cost, EEG recordings are widely used in clinical settings and research laboratories. This makes the EEG a very accessible and useful tool, which is particularly interesting for the analysis of high-level brain processes that arise from the group activity of large cell populations. The international positioning system 10-20 shown in figure 2, Is an international system that describes in which location of the skull the electrodes must be placed, for the measurement by means of an encephalogram. Prefrontal (Fp), Frontal (F), Temporal (T), Parietal (P), Occipital (O) and Central (C).

A. *Algorithms for BCI*

Some techniques and algorithms based on EEG that are used on BCI systems are presented in this section.

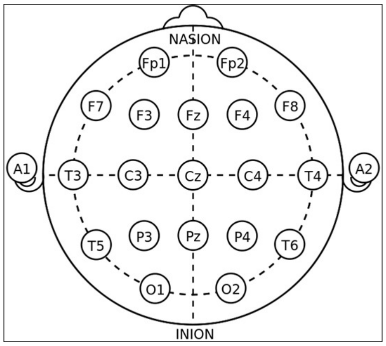

Fig. 2. Assembly of the International System 10-20 [7].

Among the algorithms that are most commonly used to design ECI-based BCI systems are: linear classifiers (Analisys Linear Discriminant, Vector Support Machine), artificial neural network classifiers (multilayer perceptron) and Hidden Markov model classifiers. The table I shows examples of algorithms that have been involved in signal processing, busy channels and their purpose in the BCI.

B. Application domains of BCI

There are three main areas in which BCI has been highlighted: Medicine, Entertainment and Art. Below are examples of BCI interfaces that have been developed, classifying them by area of application:

- Medicine.
  - Disabled people : BCIs must cover the needs of people with motor and communication disabilities, the usual applications are those that allow communication to be established, help to have some type of mobility, make it possible to control the environment, replace or restore the motor activity of some part of the body. As an example of this type of applications are:
    The Rolland III semi-autonomous wheelchair that has different input modes, such as the joystick control [18].
    The AMIGO II rehabilitation robot (Functional Robot Arm with easy-to-use interface) is a semi-autonomous system designed to assist in daily life activities [18].
    The P300 BCI spelling system consisted of the acquisition of electroencephalography connected to the real-time processing software and the keyboard display control software separately. This system was created for people with disabilities with amyotrophic lateral sclerosis [19].
  - Neuroprosthesis: Invasive BCIs allow greater control of prostheses due to their high rate of information transfer. The first BCIs were presented with a robotic arm that allowed to open and close the hand to grab and move objects, so that the user had to imagine certain movements, for example, of the hands and feet. For patients who cannot recover previous levels of mobility or communication, the BCI-based prosthetic limbs, also called neuroproteic devices, can be used to restore normal functionality. Several reality approaches have been presented for BCI-based rehabilitation training, such as real, virtual and augmented approaches. Example of movement of a robotic arm or leg by means of thought, movement of a wheelchair by means of the electrical activity of the brain [20].
  - Neurological Rehabilitation: BCIs can help people with neurological disorders such as hyperactivity due to lack of attention, memory problems, where signals are used as a mechanism to transfer information. Ref developed a system to communicate without spoken words on the battlefield, only based on the analysis of neurological signals [18].
  - Biometrics: Biometrics studies automatic methods for the unique recognition of people, based on one or more physical or behavioral traits; the identification. The recognition is carried out through statistical techniques on the physical traits (fingerprints, retina, iris, facial patterns, etc.) or behavior of an individual, in order to verify identities or identify individuals. An application of the BCI that has begun to be developed is the identification and use of brain waves for the unique recognition of human traits, where the personal password is a set of thoughts [18].

- Entertainment. There are many examples of games where BCI has been used as an entry modality. A first example of BCI in a real-world environment is a multimodal, multi-paradigm game called Bacteria Hunt. The user controls the amoeba with the keyboard. The control capacity of the amoeba is modulated by the user's alpha activity (more relaxation results in more control). The goal is to eat as many bacteria as possible. A second example is the game of sheep grazing. It is a game in which one or two players must enclose a flock of sheep (white points) in a field. They do it by directing a group of grazing dogs (black points). Another example is proposed by Danny Plass-Oude Bos, Boris Reuderink et al. AlphaWoW (Alpha-World of Warcraft), is a BCI version of Worlds of Warcraft. In this game you can control a character in a virtual environment by using the brain.[17]. Other example are Virtual reality (VR) games have been implemented, one of the most outstanding is the BCI controlled (BCIVR) based on a structure of Internet of brains (IoB) that allows multiple players from different sites to play a racing game of cars online [21].

- Art. The first example investigates a combination of BCI motor / motion prediction images with a relaxation / concentration paradigm to operate remotely controlled cars in a game application. A minimalist BCI approach is carried out using two low power wireless EEG head-

TABLE I
EXAMPLES OF BCI AND ITS ALGORITHMS

Algorithms	Signals	Objective
Artificial neural networks [8]	C3,Cz,C4,CP1,CP2,P3,Pz and P4	The classification of mental tasks (Imagination of the movement of the left hand repeatedly. (Class 2) Imagination of the movement of the right hand repeatedly. (Class 3) Generation of words that start with the same letter at random.
Transformation of Laplacian (SL) surface signals with gross potentials, estimating the power spectral density (PSD) and the SSP classifier (Projection of the signal space) [9].	F3, Fz, F4, C3, Cz, C4, P3, Pz y P4	Imagination tasks of movement to the right (RI) and to the left (LI)
Independent Components Analysis (ICA) y create a standard late ERP waveform and a deviant late ERP waveform [10]	C3 and C4	Virtual cube (moving to the left or to the right)
Fast Fourier Transform (FFT) [11]	AF3, F7, AF4 and F8	Blinking and movement of the head were selected to interact with the system (select words and phrases)
Algorithm of pre-processing of analysis of banks of flter (FBA) and a classification algorithm based on analysis of components related to tasks (TRCA), the average precision of classification using SSVEP (visual potentials evoked of stable state) [12]	PO5, PO3, POz, PO4, PO6, O1, Oz and O2	SSVEP (visual potentials evoked by stable state)
Common spatial patterns (CSP) and SVM classifier (Vector Support Machine) [13]	F3,FC3,C3,CP3,P3,FCz,CPz,F4,C4,CP4 and P4 (Frontal medial and parietal regions of the brain)	Hand exoskeleton
Classifier of linear discriminant analysis (LDA) [14]	Fz, Cz, P3, Pz, P4, PO7, Oz and PO8	Performed an action to point towards the selected token (arm movement)
FIR bandpass filter, For the c-VEP classification, a spatial filter was constructed that uses the canonical correlation analysis (CCA), to detect in which objective the user was focused, the Pearson correlation between the EEG was calculated registered [15]	T7, C3, Cz, C4, T8, CP3, CPz, CP4, Pz, PO3, POz, PO4, O1 and O2	Selection of 32 objectives (26 letters A to Z of the alphabet, as well as the underline and numbers from 1 to 5.)
Z-score, rapid detection of ocular artifacts (FEAD), Denoising Wavelet (Noise Elimination), Minimum Energy Combination Method (MEC), Canonical correlation analysis (CCA) [16]	PZ; PO3; PO4; O1; O2; OZ; O9 y FP2.	Navigating a robot that can move forward, backward, to the left and to the right
Fast Fourier Transform (FFT) [17].	O1,O2 and OZ	Bacteria Hunt Game

phones developed by IMEC, with four active-dry EEG channels each. Two players participate in a racing game controlled by BCI, selecting the directions of their cars with motor images, while controlling the speed of the car by relaxing/concentrating [22]. In the second, it shows how the same portable and wireless EEG system can be used to enrich the artistic performance of a juggler. The data from EEG headphones and motion sensors are used to transform the brain and body activity of the juggler into a sound experience, so that the audience has a richer impression of the different aspects of juggler performance [22]. The third one illustrates the development of a BCI solution that controls the cognitive state of a child during play or training. The cars were directed with the aim of completing a lap on a racetrack model. The application is implemented using the IMEC EEG software, extracting the direction of the automobile address through the supervision of the motor images and the speed of the car (stop) by using spectral power levels in all the electrodes. The study was originally designed to assess the feasibility of estimating the level of surveillance of autistic children [22].

V. USABILITY EVALUATION OF BRAIN-COMPUTER INTERFACES

It was observed that the evaluations in BCI are usually based on traditional methods (questionnaires or interviews), but very few works with the use of EEG, apart from the evaluation through questionnaires, identify emotional states through electroencephalography, combining these 2 techniques in the evaluation of usability. Below are the works in BCI that have carried out the evaluation of usability with traditional methods.

A. *Traditional evaluation*

The works of Xing et. al. [12], Chowdhury et. to the. [13], Tidoni et. to the. [14], Spüler and Martin [15], etc. Table II contains examples of Brain-Computer Interfaces that were evaluated by means of the different existing questionnaires, type of evaluation and characteristics evaluated.

However, questionnaires are likely to be contaminated by ambiguities [25] or they may be affected by social pressure [25]. It is also very difficult to obtain information in real time without interrupting the interaction. In fact, think out loud that the protocol distracts users and questionnaires can be given only at specific times, usually at the end of a session, which

TABLE II
BCI APPLICATIONS AND TYPE OF EVALUATION

Application	Method	Tool	Effectiveness	Efficiency	Satisfaction	Aspects
Interface for people with cerebral palsy [11]	Questionnaire	Questionnaire SUS			X	Easy to use
A High Speed SSVEP [12]	Questionnaire	Comfort questionnaire	X	X		Comfort, Information transfer and precision
Driven Hand Exiskeleton [13]	Questionnaire	Escala VAS		X	X	Mood, fatigue and motivation
Virtual and Robotic Agents [14]		Right selections and The total number of selections	X			Accuracy of tasks and the rate of information transfer
A high speed (BCI) [15]			X			Accuracy of tasks and the rate of information transfer
Eye Tracking Based Control System [23]	Questionnaire	TAM	X			Effectiveness
BCI Application SSVEP [16]	Questionnaire		X			Rate of information transfer (ITR)
Walk in Virtual World [5]	Questionnaire	Slater Usoh Steed	X			Presence and workload
Mouse Click [5]	Questionnaire	TLX NASA		X		workload
HamsterLab [5]	Questionnaire and Observational	VAS and video			X	Fun, frustration, control, dominance and empowerment
EEG triggered dynamic difficulty adjustment [24]	multiplayer games		X			Rate of information transfer (ITR).
Language Support Program (LSP) [19]	Questionnaire	Thinking Aloud, SUS Y (SOTU)			X	Ability to learn and ease of use
P300 Speller (P3S). [19]	Questionnaire	SUS and NASA Task Load Index (TLX)		X	X	cognitive workload and ease of use

leads to a bias due to the memory limitations of the participants. The figure 3 shows a representation of the traditional evaluation process in the Brain Computer Interfaces, indicating the method to be occupied and at what moment the evaluation is made. It can be seen that the evaluation is applied after the interaction. Indicating the above, the problems of traditional evaluation methods can be summarized in the following points:

- They do not give information in real time
- Bias or loss of user interaction information
- Manipulation or influence towards the user.

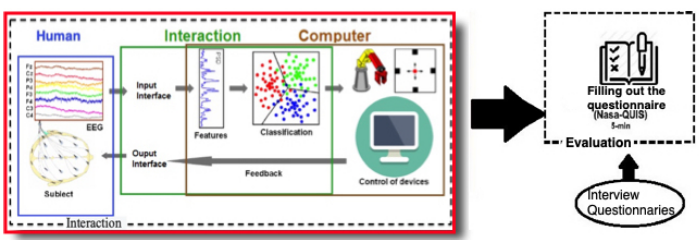

Fig. 3. Traditional evaluation methodology

Frey [25] has been suggested that portable brain imaging techniques, such as electroencephalography (EEG), have the potential to address these limitations. By this method, data is obtained in real time, information is not lost when the evaluation is done during the interaction and not later, since the evaluation in Brain Computer Interfaces already have the signals to be occupied for the interaction with the interface. The figure 4 shows a representation of the process of evaluation by EEG in the interfaces of the brain of the computer, which indicates the method to occupy and at what moment the evaluation is carried out. It can be seen that the evaluation is applied during the interaction, attacking the problems presented by traditional methods.

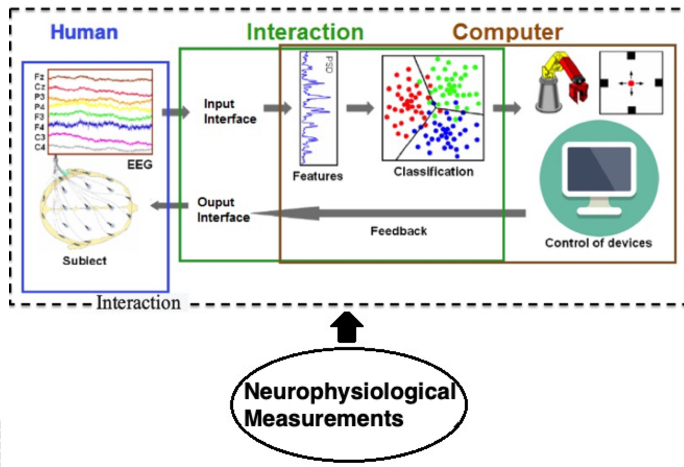

Fig. 4. Methodology of evaluation with EEG

B. Evaluation by electroencephalographic signals

Some works that occupy the EEG as a measure of usability evaluation are the following:The work of Alejandro et.al. performs the usability evaluation of an Interface for people with cerebral palsy. The main contribution of this work are the methods used in the evaluation, which are: A SUS (system usability scale) questionnaire, neurophysiological measures to evaluate the emotions of users during their interaction with the communication device, and an Analysis Observational for compare brain activity data with videos [11].

Stein et. al. [24] had suggested DDA an intelligent disability mechanism, by reducing the difficulty for the weaker player or by increasing the difficulty for the stronger player. A key question when using DDA is when to activate the difficulty setting. At work, they occupy the Emotiv EPOC EEG headset to monitor a player's level of personal emotion and use this information to activate the DDA when the player's emotion decreases to ensure the player is involved and enjoying the game.[24]

Table III presents the works of BCI applications that were evaluated by electroencephalographic signals.

TABLE III
EXAMPLES OF BCI AND ITS ALGORITHMS

Algorithms	Signs	Objective	Usability Criteria
Fast Fourier Transform (FFT) - alpha frequencies [11]	F3 and F4	Positive and negative emotion	Satisfaction
The Dynamic Difficulty Adjustment (DDA) [24]	16 channels	Frustration	Satisfaction

VI. DISCUSSION

According to the traditional usability evaluation process, we divided our evaluation into two important phases.

- The first one corresponds to the interaction. It refers to the moment of interaction with the application or interface for the user to perform the tasks or the established objectives. Making the user familiar with the Interface.
- The second phase corresponds to the evaluation of usability, where that interaction is valued by the user.

To carry out the evaluation, interviews that measure the metrics or the usability measures of the interface are used daily. These interviews are applied to users so that they value the usability of the interface. The evaluation of BCI through traditional methods has the advantage that they are validated and low cost tools. But it is done after the interaction.

With regard to the method by means of the electroencephalographic signals, only the interaction phase is presented, and it is in this phase where the EEG means the usability evaluation is carried out, which is the most important phase, the interaction of the interaction. Between the computer and the user.

The moment in which this production is evaluated is one of the main problems that has been described previously of traditional methods, such as the loss of information.

Another key point is determined by the architecture of a human computer interface. This work shows the architecture of a general human computer interface and how this architecture is better wrapped in the Brain Computer Interfaces, but you can find the clear differences in the beginning, when receiving the interface in the HCI an action (mouse , jostick, etc) and in the BCI is receiving signals, in the process of recognition of the action, etc. However, the evaluation methods remain the same for the 2 types of interfaces (GUI, BCI), with changes between these 2.

VII. CONCLUSION

Brain-Computer Interfaces - BCI seek to provide a channel for communication and control of a computer system that is not based on any movement and instead uses signals recorded directly from the user's brain to achieve interaction with a computer. [19] proposed that BCIs can be evaluated mainly in terms of efficiency, such as the accuracy of the classification and the speed of communication. In addition, several previous studies introduced the evaluation of usability dimensions in their evaluation of BCI interfaces.

It was observed that the evaluations of BCI are generally based on traditional methods (Questionnaires or Interviews), which give subjective answers, which must be interpreted without the certainty of the precision. The problems of traditional methods are: i) They do not give information in real time, ii) Bias or loss of information and iii) Manipulation or influence. Frey [25] suggested that portable brain imaging techniques such as electroencephalography (EEG) have the potential to address the limitations of traditional methods. When a person interacts with a BCI, at least one neurophysiological signal, the EEG, can already be recorded, since it is used as an input signal. There are already works that, apart from the evaluation through questionnaires, identify emotional states through electroencephalography, combining these 2 techniques in the evaluation of usability. Due to this, we observe the need to change the evaluation usability process. For it, we propose to to use the electroencephalographic signals as an input data for evaluation usability, this can decrease the evaluation time and also decrease the user's mental fatigue, obtaining more reliable data in real time.

Finally, we distinguish two branches of research to follow. The first one is the identification of characteristics that can be measured by the EEG and that influence or influence the usability evaluation in the BCI, as presented in the work of [25] where they developed a virtual environment specifically designed to validate the use of EEG as an evaluation method for HCI, using EEG recordings to continuously measure the workload, the level of attention of the users and the amount of interaction errors, but perform these measurements on an interface normal. And the research works that apply traditional methods of usability together with electroencephalography only evaluate the emotional states. The second one is the analysis and testing through the combination of different methods to contribute and improve the evaluation of usability in the BCI since there is no work that performs the evaluation of all the dimensions that comprise usability.

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