Rehabilitation of Attention System
for Treatment of Traumatic Brain Injury

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Abstract— **The main objective of the attention rehabilitation is to increase and enhance the attention level for patients who suffered from traumatic brain injury (TBI) due to certain accidents (e.g., car crash, fall, etc…). Several rehabilitation methods, which perform treatment procedures to patients, have been reported. However, each method has its unique approach to achieve the same goal and to improve the overall result of the patient rehabilitation process. In this paper, the development of an attention rehabilitation system (device and method) are reported. It is based on practicing a video game multiple times to activate the attention area in the patient's brain and to stimulate the patient's willingness to increase his/her effort to win the game. The device and the corresponding game techniques are non-invasive, safe, and to a lesser degree can be practiced autonomously. The patient can practice it at home alone or with minimal supervision. In addition, there are no associated side effects, since no pressure will be applied on the patient and no medication is required during the rehabilitation procedure.**

Keywords- Attention deficits, Rehabilitation,Videogame, Motion sensor, Wiimote, Traumatic brain injury, Wireless data collection

I. INTRODUCTION

TBI is a form of brain injury caused by sudden damage to the brain. Recent studies show that traumatic brain injuries contribute to about 30% of all injury deaths, and the leading causes are falls, vehicles crashes, recreation accidents, and violence [1]. Patients suffering from TBI face difficulties in their daily tasks since a part of their brain has its function disrupted. They also suffer from a lack of cognition for attention, concentration, processing and understanding of information, decision-making, communication, problem solving, organization, reasoning, planning, judgment, memory, controlling impulse and desires [2]. The extent of the disruption in the brain depends on the severity of the injury, whether it is mild or severe.

TBI affects different portions of patient's brain. It mainly affects the attention part leading the patient to lose the ability of gaining particular attention and processing different tasks simultaneously. This results in problems such as carrying on long conversations or sitting still for long periods of time [1]. Several treatment methods are used to perform treatment procedures to such patients and some of them can be performed in hospital, specialized clinics and can happen on an outpatient basis [3]. Some examples of attention and concentration rehabilitation are cognitive rehabilitation therapy, attention process training, and Tomatis attention assist method [4]. These rehabilitation methods are based on training the patients on functional and educational activities by using tools such as classical music or simple exercises. On the other hand, many patients who suffer from TBI will have psychosocial symptoms along with their poor concentration, such as anxiety, anger outbursts, and personality changes [5]. Rehabilitation procedure is going to be hard to perform on such patients, due to the difficulty to deal with their reactions and personalities, especially when the therapy is outside their home and in an unpleasant place such as the clinic or the hospital. Moreover, such patients may refuse to follow directives on what they should do for treatment such as the instruction of the therapist or nurse. In this work, we report the development of a device for the rehabilitation of attention and concentration deficits. The patient can practice at home, and this new method is totally safe, effective and easy.

In Section 2 of this paper, we describe an attention and rehabilitation procedure that is usually done on the TBI patients. In Section 3, a definition and explanation of the software used in this system is stated. In Section 4, the system methodology and components are clearly identified where the proposed workflow is divided into three main parts to simplify the procedure of this system; also, the steps of how the patient can use this device are stated. In Section 5, the results of testing this system on a TBI patient and on a normal person are explained with a brief comparison between these two test cases and determination of the acceptance criteria. In Section 6 we present a summary and conclusion of this new rehabilitation method and state what differentiates it from the new technologies.

II. REHABILITATION OF ATTENTION

Bennett et. al. present the definition of attention as "the ability to focus on certain aspects of the environment that one considers important or interesting and to flexibly manipulate this information" [5]. In other terms, attention is the prerequisite of enhancing the memory and increasing the brain functional activity. It actually plays an important role

in the behavior of certain person by making him/her more socially active in communicating with others. In addition, it increases the person's ability to selectively concentrate on specific information from the surrounding while ignoring other things. Furthermore, it induces quick interpretation and understanding of a problem with finding solution faster than others.

The rehabilitation of attention is the ability to restore concentration skills and activate focusing in the brain. Games, activities, and tasks can play an important role in activating the attention, enhancing the focus and the perceptual skills. There are several methods for rehabilitation of attention. However, a general procedure outlined in Figure 1 can be considered typical. This procedure includes six steps that starts with an examination of the patient's brain to determine the amount of the damage. This assessment is based on studying the function of the nervous system and evaluation of cognitive functions such as attention or memory. In other terms, it is called neuropsychological assessment [7] and it must be done prior to the treatment. Based on the results of this test, a series of cognitive and rehabilitation processes are administered to the patient. At the end of this procedure, an evaluation is performed to check the progress and consequences on the patient's brain functions.
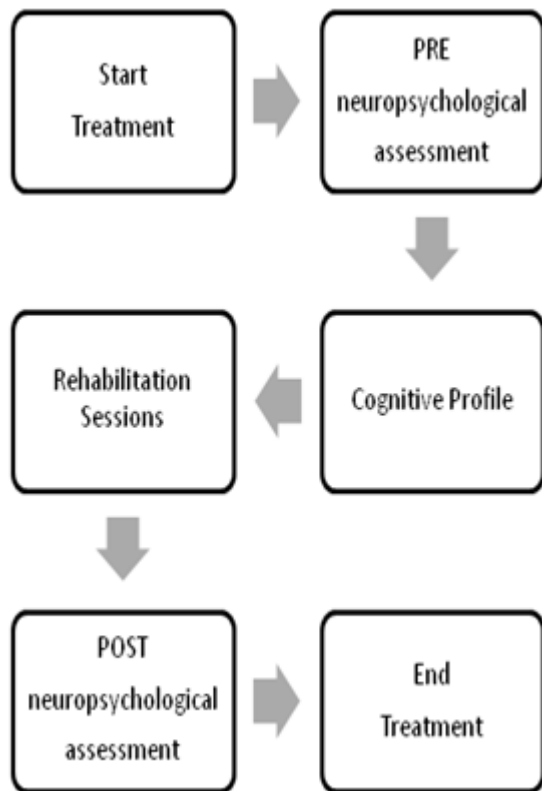

Figure 1. Typical rehabilitation general process [7].

Another important factor to be considered along with the neuropsychological assessment results is the age of the patient. The importance of this factor lies in its direct relation to the patient's brain function. The damage of a young adult brain might be totally different than that of an older person. After collecting all these information from patients, rehabilitation sessions are administered based on their cases. A recording of the patients' cognitive improvement is compiled to produce a comparison between the pre and post neuropsychological assessment.

III.   TOOLS AND METHODS

This system described in this paper provides a way of introducing patients with lack of cognition resulting from serious brain injury, brain tumor or head trauma to the first steps of rehabilitation. The system includes a hardware control device based on the MindFlex™ headset to record the brain's activities. In addition, a Wii-Mote™ is used as an free guiding device that the patient uses to control the game. The Wii-Mote™ can provide haptic feedback to the patient signaling certain events. The patient uses the headset control along with guiding device in order to move the grasping mechanism in the game (software part of the system) towards a ball with a specific color. By focusing concentration, the patient can initiate the grasping mechanism. The concentration threshold level is usually set by the rehabilitation technician. The aim of the game is to put a certain number of colored balls in their color associated basket. As the patient brain's abilities improve throughout rehabilitation, the technician increases the difficulty level of the game by changing the concentration threshold.

A.   System Architecture

As described above the brain activities are recorded by the EEG sensors built into the MindFlex™ headset. The headset is outfitted with a Wi-Fi module (ESP8266 based ESP-01). The module retrieves the data stream from the headset via its serial port and echoes the data wirelessly via UDP (User Datagram Protocol) datagrams to a computer. The Wii-Mote™, used to record the patient's hand movement, connects wirelessly as well via Bluetooth. The wireless connections free the patient from any wiring harness and thus allow for more ergonomic set-up.

The computer collecting the data runs the main software application. The application collects the data sent from the headset as well as the patient's hand movement data recorded by the Wii-Mote™.

In addition the application controls both the game's engine and GUI (Graphical User Interface). System block diagram is shown in Figure 2.

B.   Software Application

The software application is written in Processing™ language. Processing™ is an open source programming language built for the electronic arts, it is a flexible software sketchbook and a language for coding [8].
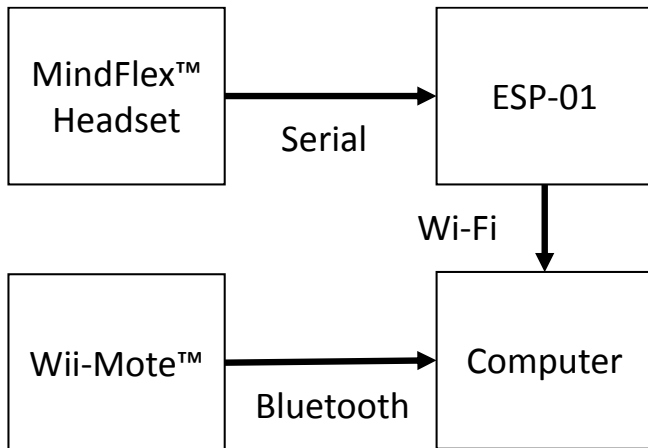
Figure 2. Proposed system architecture

This application can be used at home, hospital, clinics or any comfortable place for the patient. It is important for this application to be used in an area where there is dimmed light interface with the Wii sensor bar in order to have the optimal rehabilitation process and result of the application. The steps to follow are:

1- The patient/therapist will turn on the computer that we have already installed on the game.
2- The patient will wear the MindFLEX headset and turn it on by the button on the left side of this headset.
3- The patient/therapist will open the MindFLEX game icon.
4- The patient/therapist will click on the wireless connection network and click on MindFLEX to connect it with the game software.
5- The Wii sensor bar is connected to the computer through USB port and the Wiimote is paired with the computer by running the Wiimouse program.
6- The patient can sit or stand holding the Wiimote in forward direction toward the Wii sensor bar.
7- The patient can start the game and control the movement of the mouse cursor by holding the button A on the Wiimote, which is equal to the left click on a regular mouse.
8- The patient can press only the button A of the Wiimote in order to move the ball and he/she can move his/her hand left or right to determine the direction that he/she wants to move the ball in.
9- The patient cannot catch the ball unless his/her concentration threshold exceeds the concentration threshold set (by a slider) in the game scheme.
10- The therapist usually determine this concentration threshold based on the patient's progress but any patient can start with setting the concentration threshold to 50,which is the minimum average. The

patient can play this game as much as he/she wants per day with no force applied on the patient; in the therapeutic stages, it is better to keep following up the recording of the patient's concentration progress daily.

Depending on the threshold of concentration level taken from the patient, the ball in the game will be captured by the Wii Mote control gesture only if the concentration value above a certain threshold value in various stages of the game. As the patient goes through each stage the stage difficulty goes harder with more obstacles and high concentration level is set while a counter is recording the progress of the patient to provide the data needed for monitoring the effectiveness of the rehabilitation game program on patient activity (see Figure 3).
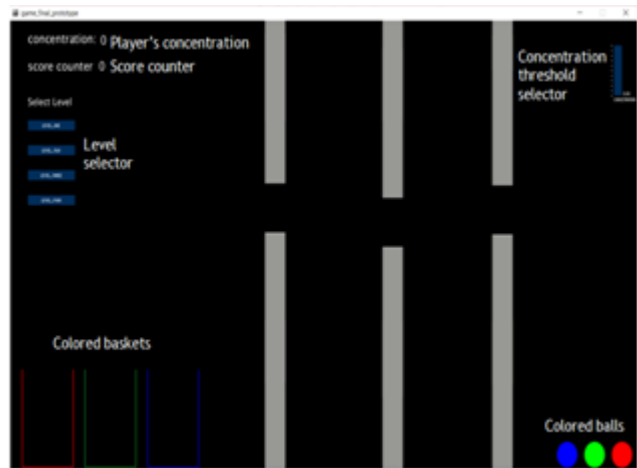

Figure 3. Game graphical user interface

IV. RESULTS

This method was tested on patient who suffers from lack of attention; also it was tested on normal person. As for normal person, he passed the first two levels with less time than that of the patient with attention deficits and the concentration threshold was set to 60, but there were some difficulties to pass the third level. Patient with attention deficits could finish the first stage where no obstacles are set in the game scheme, level 1, and the concentration threshold was set to 50 as it is considered the minimum average that such patients must easily reach in order to catch the ball in the game. It took this patient more time to finish the next level where obstacles are present; however the concentration threshold is still set to 50; and at the end it was so hard for this patient to finish the third level where three obstacles are present in the game scheme. It is important to know that is not necessary to force the patient to finish his/her level, time is not set for the patients and at the end we are trying to encourage him/her to concentrate not to leave him/her disappointed. The purpose of this rehabilitation is to train the

patient no matter how much time he/she took in this process in order to get the best result.

V. CONCLUSION

In this work, a new rehabilitation method of attention deficits is devised for TBI patients. It consists of series of brain signals detection, processing and analyzing data. The result of processing showed to be a very effective way to stimulate brain functional activity and enhance the patient's attention level. The use of simple tool to communicate with the game added a specification to this technique and increase its effectiveness compared to other rehabilitation methods. The use of this technique allows the patient to be self-active by coordinating the concentration activity with movement of hand to get through the levels and enhances the divided portion of attention type whereas the other methods lack that coordination and only focus on the focused portion of attention types. The main advantage of this rehabilitation method over other new technological devices like the smart phones with the free applications that may play role in activating the patient's brain, is that they missed the concentration monitor; for example, the puzzle game application, may help the patient to regain his/her concentration skills but there is no recorder for how much he/she is concentrating and if he/she is making a progress or no. When it comes to medical field, a real and concrete values and results must be present in order to diagnose the patient and know how he/she can be treated.

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TABLE I. HARDWARE COMPONENTS OF THE SYSTEM

Components	Functionality
Mind-Flex Headset	Embedded with an EEG sensor measures brain activity and a Neurosky chipset transmit brain signal.
ESP8266 chipset	Attached to the MindFlex headset. Sends the brain activity signal to the computer via wireless connection.
Computer	Connect to the ESP8266 chipset to receive brain signal activity. Contain processing software for processing incoming brain data to control designed game.
Wiimote controller	Connects to the computer through Bluetooth connection. Track the movement of the patient to direct the grapping pointer in the game.
Wii sensor bar	An IR transmitter to be detected by IR camera within the Wiimote. Used to set the range of motion for the Wiimote controller.