VR-Photosense: A virtual reality photic stimulation interface for the study of photosensitivity*

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Abstract. As new technologies emerge, there is an increase in the potential factors that could trigger photosensitive epilepsy. Virtual Reality (VR) contents and video games can potentially cause a response known as photoparoxysmal response, which is a well recognized phenomenon that can be diagnosed using intermittent photic stimulation (IPS). In this paper, we propose to investigate the potential risk of virtual reality in relation to photosensitivity and we introduce VR-Photosense, a virtual reality IPS software that uses different types of visual stimuli to study abnormal electroencephalogram responses in photosensitive patients, which will enable to study the impact of visually-sensitive VR stimuli in the human brain.

Keywords: Photo-sensitivity, Epilepsy, Virtual reality, Head-mounted displays, PPR, IPS, EEG

1 Introduction

Photosensitive epilepsy (PSE) is a specific form of epilepsy that normally occurs in response to certain visual stimuli. Exposure to lights flickering at a concrete frequency or brightness can pose a significant threat to photosensitive individuals, many of whom have not yet been diagnosed, so are exposed to a potential risk without knowing. As opposed to general belief, not all epileptic seizures involve convulsions or loss of consciousness, making the risk of suffering from this type of disorder appear as underestimated. Triggers such as lightning and quick

* This research has been funded by the Spanish Ministry of Science and Innovation under project MINECO-TIN2017-84804-R, PID2020-112726RB-I00 and from the State Research Agency (AEI, Spain) under grant agreement No RED2018-102312-T (IA-Biomed). Additionally, by the Council of Gijón through the University Institute of Industrial Technology of Asturias grant SV-21-GIJON-1-19.

flashes can materialize in everyday life, both in nature and while using modern technologies.

In the late 90s and early 2000s, investigations addressed the concerns about the risk of television and video games exposure, which resulted in a series of recommendations for TV manufacturers and video games developers [1]. With the advent of new devices such as plasma TVs and virtual reality (VR) head-mounted displays (HDM), factors that could trigger photosensitive epilepsy increase considerably. Virtual reality contents represent one of the most relevant possible triggers nowadays that can provoke seizures in photosensitive individuals [2], and its impact in young adults and teenagers should be considered.

In this paper the relevance of this type of VR stimulation will be discussed as well as its impact in the study of photo-sensitivity and how it can affect young individuals in their daily life. We also describe our preliminary prototype (Fig.1) which has been implemented using low-cost electroencephalogram (EEG) and virtual reality glasses with a mobile phone (Fig.2), and show how a photic driving response can be identified using the previous setup (Fig.3).

The structure of this study is as follows: Section 2, below, presents a summary of the related work. Then, we introduce VR-Photosense, the software designed by our team to detect possible abnormal EEG responses using VR, and we describe how our initial prototype is being used to measure photo-sensitivity. Finally, Section 4 presents the conclusions from this work and future research plans.

2 Related Work: Photosensitive epilepsy and virtual reality

We are facing a period of technological and environmental changes that affect visual sensitivity, with a greater impact in children and adolescents. In the following, we provide a brief background on PSE, VR technologies and detecting EEG abnormalities using intermittent photic stimulation (IPS) protocols.

2.1 The science of photo-sensitivity

Photosensitive epilepsy is estimated to have an incidence of 1.1 per 100,000 in the general population, having a considerable increase in children and young women growing up to 5.7 per 100,000. On the same line, there is a higher prevalence of photo-paroxysmal response (PPR) between the ages of 7-19, specially 11-15 years old [6]. Photo-sensitivity is an abnormal visual sensitivity of the brain, resulting in a photo-paroxysmal response (PPR), a brain epileptiform discharge, provoked by a photic or visual stimulus. It persists in at least two thirds of individuals who suffer from photosensitive epilepsy [7], but also PPRs are often detected in puberty in individuals who have never had an epileptic seizure, making women and children more susceptible to experience this type of abnormalities[6].

Being children and young adults the most vulnerable groups to suffering from photo-sensitivity, the use of video-games, computer screens and TVs can be a potential risk for these individuals. Plasma TVs and computer screens work at frequencies that are considered to be a trigger for photosensitive epilepsy [8], and despite the fact that current refresh rates are much less provocative than older TVs, they can broadcast oscillating patterns, changes in brightness [9], and alteration in color, which pose an important risk of onset while consuming media contents through the previously mentioned devices. Red and blue combinations are more provocative than red and green [10], and long wavelengths of a bright red colored light enhance the likelihood of suffering a seizure [11].

Non-photic factors such as fatigue, sleep deprivation and excitement also facilitate the occurrence of PPRs, and spontaneous seizures while playing video-games are possible [12].

2.2 Virtual reality

Among new generation technologies, virtual reality requires special consideration. VR is nowadays one of the most popular technologies for many industries and video games in particular. As of last year, Steam, the most popular gaming digital distribution service in the world, published more than 60 VR games; and its applicability is widening in areas such as medicine and education. This media industry is expected to grow up to more than 40 million worldwide shipments before 2025 [13].

Typical head mounted displays (HMD) have binocular data glasses consisting of embedded mirrors and lenses, miniaturizing display units using cathode ray tubes (CRT), liquid-crystal displays (LCD), liquid-crystal on silicon (LCos) or organic light-emitting diodes (OLED). A VR headset provided by Oculus, Rift S, is one of the most popular for video-game experiences and uses LCD with a refresh rate of 80Hz. On the other hand, low-cost HMD often make use of smart-phone devices, usually working at rates of 90-120Hz and offering a less immersive experience. As this headsets evolve, more optical enhancements are introduced, including more brightness, vivid colors and reduced screen door effects.

Although, in general, HMDs may not show potentially harmful effects on the visual system when compared with those of desktop computer displays [14], the use of VR headsets implies a wider stimulation over the visual field, which is known to increase the risk of photo-sensitivity [2]. VR headset vendors and video-game companies are already warning about the seizure development potential of their products, but much is unknown as regards the extent of the problem and the specific characteristics of VR scenarios being a PPR trigger.

2.3 Detecting EEG abnormalities using intermittent photic stimulation

Exposure to triggers normally provokes an abnormal response of the brain's electrical circuits called photo-paroxysmal response (PPR) in photosensitive individuals[3]. A precise diagnosis can be made in a controlled environment using intermittent photic stimulation (IPS) and monitoring brain activity with an electroencephalogram (EEG)[4]. High-contrast visual light stimuli produce anomalies on EEG data in photosensitive patients[5], such as a brief burst of paroxismal epileptiform activity, but this usually does not determine experiencing photo-provoked seizures in most of real-life situations. Aggressive stimulation can produce PPR in photosensitive people but does not inherently mean that seizures will occur.

Regarding the use of video games, the risk of seizure is more prevalent in males than females [15]. Flashes at a rate of 3 - 30 Hz present a higher risk of onset [8]. This is the equivalent to playing a video game with a refresh rate of 50 - 60Hz, which is the most common among video consoles at the moment. Regardless the distance to the screen, specific patterns present in games proved to be more provocative[15].

Taking into account the factors presented in this section and the increasing relevance of virtual reality, this research proposes to explore and measure the impact of photic factors while wearing head mounted displays using VR.

3 An introduction to VR-Photosense

VR-Photosense is a software designed to detect PPRs using virtual reality. As mentioned throughout the paper, lights flickering are one of the most common triggers for photosensitive responses. This software provides this scenario together with techniques used in real life IPS such as light stimulation at changing frequencies and sequence stimulation. The person is subject to these scenarios both with eyes closed and opened, in order to achieve a simulation as close as possible to conventional IPS.

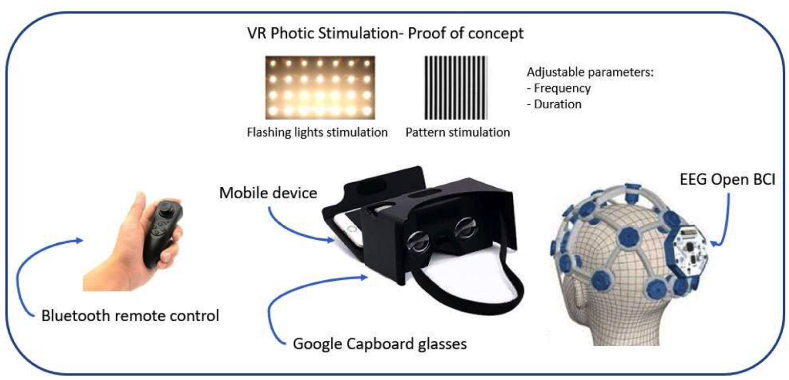

Fig. 1. VR-Photosense prototype

This solution is developed in Unity 3D[16] and it was initially tested using a Google Cardboard type of headset[17]. One of the advantages of developing with Unity is that it makes the software cross-platform and, therefore, the project can be easily exported for use with different hardware, from low-cost HMD using smartphones to high-end technologies such as Oculus VR[18], which will be used in the next stage of software prototyping and testing. Furthermore, Unity's latest Input System is used in this project making it easier and imminent to configure and offer compatibility with different types of input hardware.

VR-Photosense has been designed to facilitate the actions for neurotechnologists while conducting photosensitivity tests in the laboratory using EEG and computer displays to follow the results from the EEG and the VR simulation in real time. All configurations are keyboard driven, as this is more familiar than using VR remote controls and it also gives a wider range of options.

Introducing an innovation to conventional IPS, VR-Photosense allows the color of the flickering light to be changed to either bright red and bright deep blue. These tones combined are more provocative respectively, allowing to study brain behaviour reacting to stimulation with both of these scenarios. The bright red light is combined with a deep blue background, making this combination a powerful trigger for photosensitivity, whereas deep blue lights are combined with a white background to obtain the opposite effect. The default colors are a white light with black background to achieve a high contrast stimulation.

3.1 Measuring photo-sensitivity with VR-Photosense

The first set-up for testing is fairly simple. After downloading and starting the app on an Android device, it is inserted in the head mounted display. The headset is then secured to the patient's head using the adaptable straps leaving the upper part of the head clear. Finally, the OpenBCI EEG[19] is easily set up on the patient's head covering all necessary points of contact.

Fig. 2. VR Photosense set-up.

The neurophysiologist can configure the frequency of the stimulation in an increasing or decreasing pattern, ranging between 1Hz and 50Hz (in general, photosensitive responses occur within 8Hz and 30Hz). The sequence is set to work as follows: seven seconds of stimulation and ten seconds of rest. Each cycle of stimulation has a higher or lower frequency of stimulation depending on what configuration is previously set. Due to safety reasons, the stimulation can, and must, be paused and resumed whenever needed, making it a safe environment for the patient in case of presenting a PPR or even milder reaction.

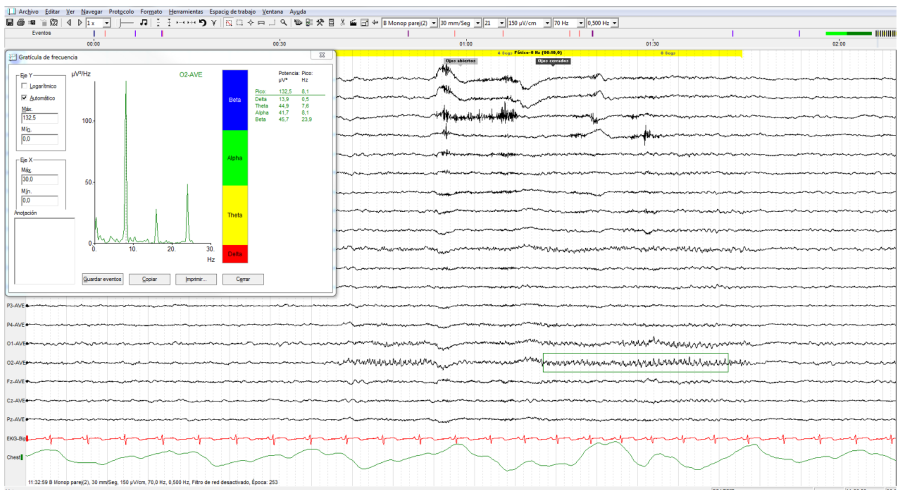

Fig. 3. Average montage. Photic driving response in occipital regions, at the flash frequency (8Hz) and harmonic frequencies of 16Hz and 24HZ.

As a starting point, the easiest EEG response to look for is a photic driving response due to it being a common physiological response to light during the photic stimulation. Photic driving response is elicited by an intermittent photic stimulation of the retina that can be pointed out in the alpha rhythm [20]. It is a physiological response that consists of brain activity time-locked to and at the same frequency or at an harmonic frequency of the flash stimuli[21] (see Fig.3). It is usually greatest when the light stimulation approximates the patient's alpha rhythm.

In this initial data collection, we aim to understand and provide a first statistical evaluation of EEG metrics related to the use of our VR-based IPS software. Once this tool is adequately attested and refined, conducting a clinical trial is required in order to validate the full functionality of VR-Photosense and its clinical value when testing for PPRs.

4 Conclusions and future directions

As new VR applications are being discovered and its use becoming widespread, it also poses new challenges and research questions associated with the use of visual contents on a new medium. One of those questions is whether and to what extent VR exposure increases the risk of seizure development for photosensitive patients.

In this research, we propose extending the current investigation of the risk of photosensitivity while consuming media contents using VR head-mounted displays and we introduce VR-Photosense as an affordable approach to study such responses, determining the incidence of photic driving responses and the impact of VR visual stimuli on photosensitive users.

Our upcoming investigation will explore an alternative approach to PPR detection by inserting AI to the clinical flow and a comprehensive photic stimulation covering not only flashing lights and patters but also enriched scenarios defined as potential PPR triggers. This project also proposes to develop a Brain Computer Interface (BCI) in close collaboration with leading neurophysiologists to incorporate VR and deep learning (DL) to photic stimulation. The proposed BCI will allow the assessment of VR's effects on photosensitivity and the evaluation of its potential clinical use for PPR detection.

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