VR4NEUROPAIN: Interactive Rehabilitation System

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Abstract: Virtual Reality (VR) has finally found its way to be used in the healthcare industry, covering many different areas such as medical training, marketing, patient education, psychotherapy and physiotherapy, and many others. The need to develop increasingly personalized technology to be used during the rehabilitation process is extremely important. Therefore, the VR4NeuroPain solution aims to cover the unique influence that it obtains from the VR applied to the rehabilitation area, creating unique and virtual spaces where patients with neuropathic pain can be submitted to their therapy sessions, not only in hospitals and clinics, but also at home. The VR4NeuroPain system monitors electrophysiological data in real time, and consists of the following components: Virtual Reality Interface, Plataform and a Glove-"GNeuroPathy". The main objective of this paper is to describe all the components of VR4NeuroPain solution. The system can be used by physicians, occupational therapists and physiotherapists. VR4Neuropain allows the use of innovative and interactive intervention methodologies.

1 INTRODUCTION

VR4NeuroPain is a customized solution of interactive technology that aims to promote the rehabilitation of patients with neuropathic pain in a hospital or home environment. This innovative system combines virtual reality headsets, haptic feedback gloves with motion and biomedical sensors allowing the collection and analysis of physiological parameters. This approach while is used as a rehabilitation facilitator, the patient is also immersed into a virtual world where he can perform several gamified tasks. These required tasks are specified physical exercises prescribed and recommended by therapists under conventional therapy but with the plus of the virtual reality world engagement that increase the patient motivation.

VR4NeuroPain aims to promote rehabilitation of Stroke patients, Spinal cord Injury patients,

Neuropathic Pain, physiotherapy, as also promote active ageing.

The stroke is one of the main disability factors of the upper member causing functional losses associated with cognitive and perceptual disorders (Thrift, 2017). With the currently used intervention methods in the conventional rehabilitation process, 30% to 60% of the individuals that suffered a stroke will not regain their competencies effectively.

Worldwide, the incidence of Spinal cord Injury ranges from 3.6 to 195 per million leading to a major medical problem (Massetti, 2018).

Neuropathic pain is a type of chronic pain caused by damage or disease affecting the central nervous system and can affect anyone. It manifests itself in various ways such as burning sensation, weight, needle sting and shocks. Up to 7% to 8% of the European population is affected by neuropathic pain (Liedgens, 2016). Among people in the US reporting at least some pain in the last year, 15.7% likely had a

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syndrome with a neuropathic component (DiBonaventura, 2017).

Laver et al. (2012) refer that virtual reality seems to be a promising technology, however, currently, the studies are few and do not ensure the occupational interests of individuals, nor allow an active participation of caregivers. Computer games will be part of the future of healthcare and personalised healthcare system (Yannakakis, 2012). The games should be integrated into contingency plans for its high potential (Mc Callum, 2012).

On the other hand, the acquisition of biosignals has been increasingly used to monitor the physiological and biomechanical parameters, thus helping, in the definition of the intervention plan. So, the human activity monitoring by wearable electronic equipment is a new research area and it has been growing constantly over the past years. This approach is possible due to the easy self-adapting sensors, which provide the collected data to be processed to obtain the relevant analysis of the biosignals. Furthermore, the optimal combination of the sensors used (less as possible) and the data collected (much as possible) could provide a simple, but complete, health monitoring system.

Despite the portable systems are easy to use with these procedures, when monitoring requires extensive periods of time, the use of wearables devices is the most suitable method. Its implementation has a severe impact on some health assessment and interventions on the patient's and on the patient's clinical evolution.

Aligned with the wearable devices and the ubiquitous computing resources, the opportunity to use biofeedback therapy emerged. Biofeedback is a technique of training in which a person learns how to control involuntary bodily functions using the devices and it is increasingly used in clinical. Therefore, the real-time acquisition enables the subject to control involuntary bodily functions and the clinician can monitor in a real context.

So, biosignals and virtual reality, due to their impact importance, are relevant methodologies to be applied in rehabilitation

Therefore, an innovative solution was developed named "VR4NeuroPain", which associates virtual reality with sensory and motor stimulation (Quaresma, 2018). The system consists of the following components: Virtual Reality Interface, Platform and a Glove - "GNeuroPathy", that monitors electrophysiological data in real time.

The "VR4NeuroPain" system was developed to play an active role in the rehabilitation process,

promoting patients' quality of life and well-being. It is based on the following therapeutic objectives:

- Performing fine and global movement;
- Distinguish tactile sensory stimuli;

The "VR4NeuroPain" also aims to motivate the rehabilitation process and stimulate technological literacy.

For that reason, the use of interactive technologies in rehabilitation process allows to reduce the time spent in that process and greater economic sustainability of the units of the health sector. In order to guarantee the applicability of the system it is necessary to carry out the validation of all the components. Therefore, one of the components of the "VR4NeuroPain" is the "GNeuroPathy" and has already been applied in people with no associated pathology and it has been found to be easy to apply and meets the proposed objectives (Quaresma et al., 2018).

It allows the integration in the conventional rehabilitation of interactive and playful methodologies that are in tandem with the motivations and occupational interests of the patients.

2 MATERIAL AND METHODS

The study was approved by the Portuguese Ethics Committee of the Medicine and Rehabilitation Center of Alcoitão, in Portugal.

The components of VR4NeuroPain solution are (Figure 1): Haptic feedback Device, Glove "GNeuroPathy" System, VR4NeuroPain Platform and VR Game.
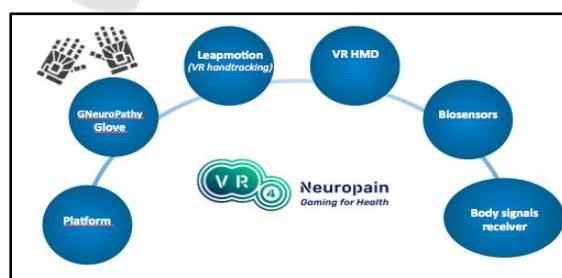

Figure 1: VR4NeuroPain Solution components.

2.1 Haptic Feedback Device

For the haptic feedback device will be used the ESP32 BLE (development Board WiFi+Bluetooth Ultra Low Power Consumption - Dual Cores) placed inside a wrist band and wired connected to 5 small

vibrator motors (4.0 cm x 1.0 cm x 0.3 cm / Rated Voltage: DC 3.0V) embedded in the underside of each "GNeuroPathy" glove's fingers.

This device will be powered by a 3.7v battery while is bluetooth paired with the developed software providing different vibration patterns for each several virtual stimulus controlled by the therapist.
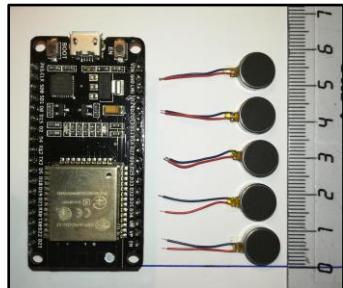

Figure 2: On the left - esp32 development board with Bluetooth low energy embedded (BLE).

On the right - the vibration motors that will be placed inside the glove's fingers.

2.2 Glove "GNeuroPathy" System

The "GNeuroPathy" system is a glove that monitors electrophysiological data in real time. During the design process of "GNeuroPathy" it was necessary to take into account a set of requirements. Therefore, it was decided that the "GNeuroPathy" should:

- Allow integration of muscle activity with eletri-miography (EMG) and electro-dermal activity (EDA) sensors and not interfere with therapy performance.
- Be portable.
- Be light, comfortable and not interfere with the tasks performed by the subject. must be adaptable to various sizes of hand.
- Allowing a more real interaction with the subject and the object being manipulated.
- Be cheap for use by doctors and patients.
- Recreating a different sense of touch.

The "GNeuroPathy" glove (Figure 3) is easy to put on, allows object manipulation and integrates two types of sensors that collect EDA and EMG data. To record the EMG and EDA signals, a Bitalino * acquisition module, 2 EMG sensors and 2 EDA sensors were used. To connect the sensors to the subject, 2 Ag / AgCL with adhesive electrodes nailed with solid adhesive were used by sensor (TIGA-MED Gold 01-7500, TIGA-MED GMBH, Germany).

Usability validation that examines subject's degree of satisfaction when using the glove (Quaresma et al., 2018).

Figure 3: The glove "GNeuroPathy".

Bitalino (Figure 4) records the biological signals simultaneously with a 16-bit resolution and sampling frequencies up to 1000 Hz. All data is transmitted via Bluetooth. To record the data transmitted from Bitalino, the software used was Plux OpenSignals.

Figure 4: The components of the Bitalino and the EDA sensors (Guerreiro et al., 2013; Guerreiro et al., 2014).

2.3 VR4NeuroPain Platform

The VR4NeuroPain platform is a responsive web-based solution and has the objective to help promote the rehabilitation of patients with neuropathic pain, through integration with the VR4NeuroPain solution (Figure 5). The platform can be used on desktops, laptops, tablets or mobile phones.

The VR4NeuroPain platform is composed of a database where is recorded all the information about patients, physicians, rehabilitation sessions schedules, configuration parameters for virtual reality games and scenarios, and other important information. The platform has also many user-friendly web pages created for registered users to manage all the necessary information.

The platform allows access to two types of users: clinicians (such us physicians/occupational, therapists) and platform administrators.

The physicians/occupational therapists can record all clinical information of patients such as age, diagnosis, evaluation of rehabilitation parameters for patient sessions. They can also manage the schedule of their patient's rehabilitation sessions and have also access to reports and dashboards to assess the evolution of the patients.

The administrators manage the VR4NeuroPain platform, doing operations like configuring new users to access the platform, manage all rehabilitation sessions schedule, payments of sessions and they are also responsible in the configuration of all parameters of virtual reality games and scenarios used in VR4NeuroPain rehabilitation sessions and based on physicians requests.
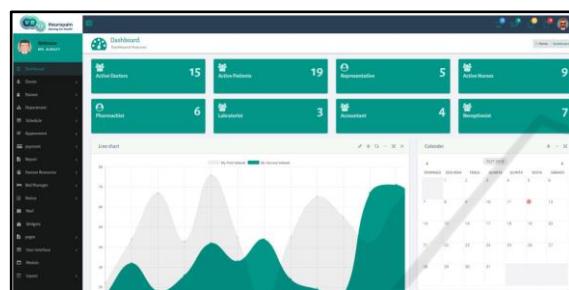
Figure 5: The VR4NeuroPain Platform.

The VR4NeuroPain platform was created using WordPress which is a free and open-source content management system (CMS) based on PHP and MySQL. Wordpress is used by more than 60 million websites and is the the most popular website management system in use. Some areas of the VR4NeuroPain platform were customized using a template and applying several programming languages such as PHP, HTML, JavaScript and CSS. The database was based on MySQL which is an open-source relational database management system (RDBMS). To create the database the language chosen was SQL.

2.4 VR4NeuroPain Game

Virtual Reality has great capabilities in person's embodiment and sense of presence inside virtual environments (Pozeg, 2017), where the user can really feel that they're living that virtual experience. Because of this, VR become commonly used among medical treatments due the fact that the virtual environment variables are more likely to be controllable and repeated. From phobias (Banos, 2002), motor cortex rehabilitation due stroke conditions (Alves, 2018) to spinal-cord injury

focused either in neuropathic pain improvements (Villiger, 2013), studies have shown that this technique is sustainably promising.

For example, (Villiger, 2013) found that Two thirds of the patients improved, immediately after the treatment and 12 to 16 weeks after treatment, showing long term effects, probably due beneficial effects of visual illusions on pain as they point on this study.

Said that, we expect either positive results with our approach, once literature present positive evidences.

The VR4NeuroPain game is a VR real-time rendering application made with the Unity engine, that enables neuropathic pain patients to undergo physical therapy at hospitals, clinics and also at home. By tracking the patient's movements and bio-signals, the app is capable of monitoring posture, tracking therapy performance, correlate exercises with bio-signals and much more.

By using the Leap Motion interface as means to interact with the virtual environment we are removing the need for another physical interface to be used by the patient, thus allowing for a more natural and intuitive human machine interface (HMI) that will not require the adaptation of hand-based exercises. Interactivity with the environment has been designed so that patients mimic everyday actions like pressing buttons or moving levers each time they are interacting with the virtual world.

Project Chatrooms is a multiplayer, multiplatform framework that enables multiple users to connect to the same virtual space and interact with one another. As such, it makes VR multiplayer development faster, easier, affordable and customized for developers.This framework is Hardware Agnostic - runs on all VR hardware and non-VR on PC and Mac; Engine Agnostic - Unity and Unreal engines supported; Multiplayer Services Agnostic - Photon, GameSparks, SpatialOS or any other solution and supports Haptic gear and other VR specific equipment.

Thanks to the Project Chatrooms multiplayer VR framework, VR4NeuroPain may have health professionals following patients in real-time from anywhere in the world. Not only are they capable of joining the same virtual world (and therapy session) to monitor the patient's exercises, but they also have real-time access to the patient's bio-signals.

2.5 Branding

VR4NeuroPain is a state-of-art scientific product with a commercial purpose that aims to upgrade

neuropathic patients therapies with portable therapy. As it's about to improve patients quality of life, the brand identity strategy was based on how important was to keep the visual message straight and effective to those who will benefit on it.
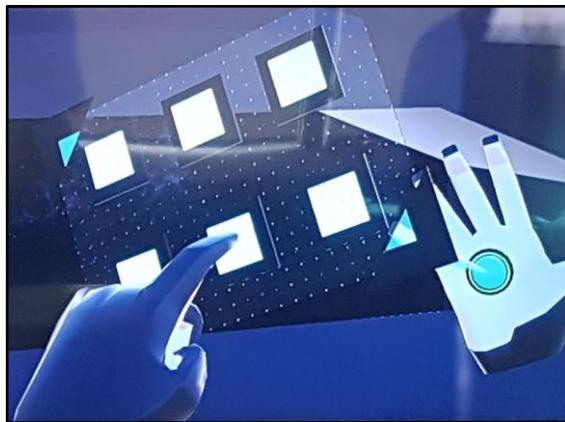
Figure 6: The VR4NeuroPain Game.

2.5.1 Brand Visual Solution

The approach to the graphic identity solution comes down to the visual translation of the users experience - VR Glasses, which take the patient to a virtual therapy room, and biosensors gloves that connect that virtual reality with tactile stimulation (Figure 7).

Round and smooth shapes illustrates the flow of this experience with a real human purpose, and at the same time an hidden matrix structuring different levels of information.

The brand will predominantly live on screens, so using gradients was an opportunity to reinforce the flow concept and to make it feel bright and alive. Dark blue and electric green were combined as a positive standout palette that can grow over time.

In application, it's mostly about the gradient offset rounded shapes demanding the attention of VR4NeuroPain main asset - sensory vibration - which can be sized and cropped in different layouts that create tension and make good use of free space.
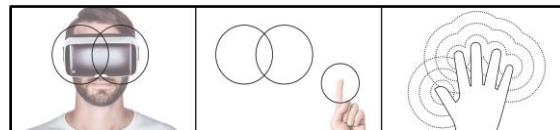

Figure 7: Brand visual solution.

3 CONCLUSIONS

The principal objective of this article is to present an ongoing project for system development named "VR4NeuroPain". In order to guarantee the applicability of the system it is necessary to carry out the validation of all the components.

In the future will be developed software with algorithms of processing of physiological signals, such us EDA and EMG. These algorithms must allow the correlation of the mentioned biosignals. In addition, the glove - "GNeuroPathy" must also be validated associated with the other parts of the system. Tests in individuals with neuropathic pain will be performed with the "VR4NeuroPain" and compared with the conventional procedure in order to prove that this is a reliable system.

The system can be used by multiple users and will allow us to apply innovative and interactive methodologies of intervention promoting the process of rehabilitation.

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