Towards a Human-Centered Approach for VRET Systems: Case Study for Acrophobia

Oana Bălan[1(✉)], Ștefania Cristea[1], Alin Moldoveanu[1], Gabriela Moise[2], Marius Leordeanu[1], and Florica Moldoveanu[1]

[1] University POLITEHNICA of Bucharest, Bucharest, Romania
{oana.balan,alin.moldoveanu,marius.leordeanu, florica.moldoveanu}@cs.pub.ro, stefania.cristea@gmail.com
[2] Petroleum-Gas University of Ploiești, Ploiesti, Romania
gmoise@upg-ploiesti.ro

Abstract. This paper presents a human-centered methodology for designing and developing Virtual Reality Exposure Therapy (VRET) systems. By following the steps proposed by the methodology – Users analysis, Domain Analysis, Task Analysis and Representational Analysis, we developed a system for acrophobia therapy composed of 9 functional, interrelated modules which are responsible for patients, scenes, audio and graphics management, as well as for physiological monitoring and events triggering. The therapist visualizes in real time the patient's biophysical signals and adapts the exposure scenario accordingly, as he can lower or increase the level of exposure. There are 3 scenes in the game, containing a ride by cable car, one by ski lift and a walk by foot in a mountain landscape. A reward system is implemented and emotion dimension ratings are collected at predefined points in the scenario. They will be stored and later used for constructing an automatic machine learning emotion recognition and exposure adaptation module.

Keywords: Virtual reality · Exposure therapy · Human-centered · Acrophobia · Phobia

1 Introduction

Phobia is a prevalent anxiety disorder of our times, affecting 13% of the world's population. They are characterized by an extreme fear of objects or situations, distressing panic attacks and physical symptoms such as sweating, trembling, rapid heartbeat, headaches, dizziness, confusion and disorientation. In severe situations, some people experience psychological symptoms such as fear of losing control or even fear of dying. Phobias are divided into 3 categories – social phobias (fear of meeting people of higher authority, using a telephone or speaking before a large crowd), agoraphobia (fear of open spaces)

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and specific phobias, which are generated by specific objects or situations. In what concerns social phobias, they affect people of all ages, but usually appear in adolescence. 45% of people with social phobias develop agoraphobia and the fear of having an anxiety attack in public or embarrassing themselves, while 17% develop depression [1]. 15–20% of the world's population experience specific phobias at least once in the lifetime [2]. At world level, specific phobias have the following prevalence: acrophobia (fear of height) – 7.5%, arachnophobia (fear of spiders) – 3.5%, aerophobia (fear of flying) – 2.6%, astraphobia (fear of lightning and thunder) – 2.1%, dentophobia (fear of dentist) – 2.1% [3]. The annual total costs of social phobia were 11.952 euros in the Netherlands, higher than the total costs for people with no mental disorder, of 2957 euros [4]. As concerns the European Union, the direct (diagnosis and treatment) and indirect (invisible costs associated with income losses due to mortality and disability) costs were estimated at 798 billion euros. They are expected to double by 2030 [5].

Of the people suffering from social phobias, only 23% seek specialized help. 80% of the patients turn to medicines and Cognitive Behavior Therapy (CBT), a method of gradual in-vivo exposure to stimuli and thought control. Unfortunately, only 50% of the persons suffering from social phobias and 20% of those affected by specific phobias recover completely [1].

Besides CBT and in-vivo exposure, a new therapy has emerged, namely VRET (Virtual Reality Exposure Therapy). The user is presented a computer-generated virtual environment, either on a desktop or mobile platform, via a Head Mounted Display (HMD). Virtual environments can be easily controlled by the therapist, customized and adapted to the condition of each patient. They are immersive, appealing, cheap and most importantly, safe. Over 80% of the patients prefer virtual exposure therapy over the classical in-vivo exposure [6]. VRET has a strong stability of results in time, equal to that obtained by CBT therapy [7]. However, it is appropriate for people who do not possess high imaginative skills such as those required for CBT. It also provides a more comfortable sensation than in-vivo exposure, knowing that it is only a virtual immersion from which you can abscond as soon as you feel like losing control.

In this paper we propose a methodology inspired from the HCDID model proposed by Zhang et al. in [8] and from the NADI model of van der Bijl-Brouwer and Dorst [9] for designing and developing a VRET system. It is quite a difficult task to provide a proper methodology for medical software development because it needs to take into account the complexity of human biology.

In addition, we provide a case study for acrophobia therapy. Such, we designed a virtual environment illustrating a mountain scenario where the user can ride by cable car, ski lift and walk by foot. The therapist can manage the patients, visualize their physiological parameters and adapt the scenario accordingly. The design is human-centered, thus it meets both the patients' and therapists' requirements. In our opinion the human-centered design for software means also to understand people (feelings, emotions, ideals, aspirations, needs, habits, motivations, and so on) and provide software tailored to each individual.

In this phase of research, we collect data from the users and from the therapists (biophysical signals, actions performed in the virtual environment, user behavior, general performance, the modality in which the clinical specialist reacts to the patient's performance and physiological data, adapting the exposure scenario accordingly). This data will be used for constructing a computational model with various feature extraction and machine learning techniques that will automatically recognize human emotions and adapt the virtual exposure in real time.

The paper is organized as follows: Sect. 2 presents existing systems for phobia therapy, Sect. 3 describes the emotion models, Sect. 4 presents the human-centered paradigm, Sect. 5 is dedicated to our proposed human-centered VRET system design methodology and Sect. 6 introduces a case study, the development of a VRET system for acrophobia treatment. Finally, we show the study's conclusions and provide future directions of research.

2 Virtual Reality Systems for Phobia Therapy

In order to perform a comprehensive analysis of the existing Virtual Reality (VR) systems for phobia therapy, we considered 3 main categories: platforms, applications for desktop and mobile devices and systems developed within an academic research.

2.1 Platforms

C2Phobia software [10] is composed of more than 70 configurable exposure environments (the therapist can add/remove elements from the environment) for treating a wide range of phobic conditions: Acrophobia, Agoraphobia, Claustrophobia, Ochlophobia, Arachnophobe, Aviophobia, School phobia, Fear of public speaking, Fear of pigeons, Fear of dogs, Fear of cats, Fear of the hospital. The patient is exposed gradually to different levels of anxiety according to his pathologies. PSIOUS [11] provides over 50 resources (VR and augmented reality environments, 360º videos) with real-time view of what the patient is seeing during the session. Stim Response Virtual Reality [12] offers fully modular environments for acrophobia, fear of flying and fear of public speaking therapy. The events from the virtual or augmented world and the physiological data (ECG, EEG, EOG, EMG, EGG, EDA, temperature, respiration, pulse) are synchronized. Virtual Reality Medical Center (VRMC) [13] uses VRET in combination with biofeedback and CBT to treat phobias (fear of flying, fear of driving, fear of heights, fear of public speaking, claustrophobia, agoraphobia), anxiety (including pre-surgical anxiety), stress and chronic pain. This system is used also for treating post-traumatic stress disorder caused by military deployment. Each stage can be repeated until the client feels comfortable. At every step, the therapist can see and hear what the client is experiencing. If the level of anxiety becomes too high, the user can return to a lower level or exit the virtual world. Virtually Better [14] offers Bravemind, a system for alleviating the psychological repercussions of war for the soldiers who served in Iraq or Afghanistan. Bravemind is accompanied by vibrotactile feedback (sensations associated with engine rumbling, explosions, firefights), ambient noises and scent machines. Limbix [15] offers VR environments built from panoramic images and videos. The scenes are interactive, so that the therapists can change them in real-time. PHOBOS [16] is designed for individuals, professionals and organizations. It ensures gradual exposure to stimuli and interactive 3D environments that address agoraphobia, social anxiety disorders and specific phobias.

2.2 Applications for Desktop and Mobile Devices

For acrophobia therapy, the most popular games are The Climb [17], Ritchie's Plank Experience [18], Samsung Fearless Cityscapes [19] for Gear VR, Samsung Fearless Landscapes [20]. In Arachnophobia [21], the user looks at specific spots on a piece of paper in front of him and is able to control the amount of exposure to virtual spiders. Limelight [22] for HTC Vive puts the user on stage in front of a virtual crowd that can change its mood and behavior. For treating fear of public speaking, he can give presentations in business meetings, small classrooms or large halls.

2.3 Systems Developed Within the Academic Context

Acrophobia Therapy with Virtual Reality (AcTiVity-System) [23] uses Oculus Rift to render the 3D scenes, a Microsoft Kinect for motion tracking and a heart rate sensor. A large experiment, involving 100 users, took place in order to evaluate the system and the results showed that all the participants in the VR group recorded a certain level of fear reduction, with the average reduction being 68%. Half of the participants in the VR group had a reduction in fear of heights by over three quarters. VR Phobias [24] contains a static environment depicting the view of a hotel balcony. The results of an experiment involving 15 users showed the same rates of success for the users treated in a virtual environment and for those exposed to a real-world environment. However, the virtual sessions were shorter (22 min), compared to the real-world ones (51 min). The acrophobia system developed at University of Amsterdam and Delft University of Technology [25] comprises three different virtual environments: a mall, a fire escape and a roof garden. 29 patients have been exposed to these virtual environments in the presence of the therapist. At the end of the experiment, the subjects have reduced their anxiety and avoidance levels.

3 Emotion Models

Some of the most challenging subjects in psychology are related to emotions, emotional-eliciting stimuli and the modalities of measuring affective changes. There are many theories of emotion, with each author offering his own perspective on the topic. In 1969, Izard concluded that the area of emotional experience and behaviour is one of the most confused and ill-defined in psychology [26]. The most relevant researcher in the field, Paul Ekman, stated the following about basic emotions and their facial expressions-based recognition: My views over the past 40 years have changed radically from my initial view that: (a) a pleasant-unpleasant and active-passive sale were sufficient to capture the differences among emotions: and (b) the relationship between a facial configuration and what it signified is socially learned and culturally variable. I was forced to adopt the opposite view by finding from my own and others' cross-cultural studies of facial expressions [27].

Emotions have a complex and multi-aspect nature. According to H. Hockenbury & E. Hockenbury, emotion is seen as a complex psychological state that involves three distinct components: a subjective experience, a physiological response and a behavioral or expressive response [28].

Cabanac proposed the following definition: *emotion is any mental experience with high intensity and high hedonicity (positive or negative)* [29]. The causes of emotions are various and they can be recognized through *signs of emotions*, *as sweating, tachycardia, facial expressions.*

While a review on emotion literature in psychology is beyond the scope of this paper, we adopt the definition proposed by H. Hockenbury & E. Hockenbury and present the most relevant emotion models and key concepts used in emotion recognition.

Regarding the emotion models, there are mainly two perspectives: discrete and dimensional. In the discrete model, it is assumed the existence of a basic set of emotions. Ekman and Friesen identified six basic emotions: anger, disgust, fear, happiness, sadness, and surprise [30]. Later, the list was updated including embarrassment, excitement, contempt, shame, pride, satisfaction, amusement, guilt, relief, wonder, ecstasy and sensory pleasure. In the dimensional model, an emotion is described by two or three dimensions, which represent fundamental properties. Russel suggested in his circumplex model of affect the usage of two dimensions: the arousal or activation dimension to express the intensity of emotion and the valence dimension to express the way in which the emotion is felt, either positive or negative [31]. Dominance was related to the extent to which a person can control his behavior. Nowadays, valence, arousal and dominance are still used as three basic dimensions to express the emotional states. Each discrete emotion can be viewed as a combination of two or three dimensions [32, 33]. For example, fear is characterized by negative valence, high arousal and low dominance.

Complex emotions can be constructed from combinations of basic emotions. Robert Plutchik introduced the famous wheel of emotions to illustrate how basic emotions (joy versus sadness; anger versus fear; trust versus disgust; and surprise versus anticipation) can be mixed to obtain different emotions [34]. The Pluthcik's model is not the only tool used to assess emotional reactions. Geneva emotional wheel (GEW) uses a circular structure with the axes defined by valence and control to arrange 40 emotion terms in 20 emotion families [35]. More information regarding the usage of GEW tool can be found at [36].

Many laboratory experiments have been carried out in order to study emotions. In [37], a comparative study regarding the capacities of pictures and films to induce emotions is provided. The Self-Assessment Manikin scale was used to rate the emotion and arousal states [38]. The results obtained were unexpected: films were less effective than pictures stimuli. Two stimuli were used in [39] to induce emotional states: self-induced emotional imagery and audio/video clips. Electroencephalography (EEG) brain signals were automatically analyzed and used to recognize human emotions. Facial expressions, posture, voice, body motion reflect emotional states [40–43]. With the development of technology, various data could be acquired and processed, thus leading to automatic emotion recognition systems development. The best performance is achieved by multi-modal emotion recognition.

4 The Human-Centered Paradigm

Nowadays, we are witnessing the explosion of the Human-Centered paradigm. There are many definitions which attempt to encompass various aspects of human-centered.

We find human-centered related to with different concepts such as computing, design, systems, machine learning, software engineering and so forth.

In the final report of the workshop Human-Centered Systems (HCS): Information, Interactivity, and Intelligence, 1997, the participants agreed and defined the human-centered systems as *an emerging discipline that combines principles from cognitive science, social science, computer science and engineering to study the design space of systems that support and expand fundamental human activities* [44]. Jaimes et al. notice that the aim of Human-Centered Computing (HCC) is the tight integration of human sciences and computer science to build computing systems with a human focus from beginning to end [43].

Human-centered Machine Learning (HML) proposes a new approach for Machine Learning (ML) algorithms. They consider human goals and contexts in designing ML algorithms, so that ML becomes more useful and usable [45]. The human and the computer have to adapt to each other: the human can change the behavior of the machine and the machine can change the human's goals. Applied ML is seen as a co-adaptive process with the computers being part of human design process [45].

Generally speaking, the Human-Centered Design (HCD) deals with those methods and principles used to design and develop any types of services or products for people, taking into account the utility, pleasure and meaning parameters [42]. van der Bijl-Brouwer and Dorst developed the NADI model based on four layers of human Needs and Aspirations for Application in a Design and Innovation process [9]:

I Solutions – shows what the people want or need

II Scenarios – describes how the people interact with a solution in a specific context of use

III Goals and **IV Themes** – are the deepest levels and describe the reasons why people want a certain solution. The authors showed the difference between goals and themes: the goals take into account the context of the problem, while themes deal with the context-free analysis of underlying needs and aspirations.

NADI is a general model for product design; it is not dedicated to software. It focuses on needs and aspirations in order to capture the long-term desires, hopes and ambitions.

In 2003, Seffah and Andreevskaia noted that the HCD techniques are still insufficiently integrated in software engineering methodologies [45]. They provided a comprehensive guide to teach engineering programming in terms of the human/user-centered design (UCD).

Considering the movement of software engineering from the traditional software development to the human-centered development, Seffah, Gulliksen, and Desmarais proposed the following process features: user-driven; solution focus; multidisciplinary teamwork including users, customers, human factor experts; focus on external attribute (look and fell, interaction); quality defined be user satisfaction and performance (quality in use); implementation of user-validated solution only; understanding the context of use (user, task, work environment) [46].

In [47] a Human-Centered Distributed Information Design (HCDID) methodology is introduced and it is demonstrated on electronic medical records systems. HCDID is based on the theory of distributed cognition, which claims that the unit of analysis is the system composed of human and artificial agents, the pattern of information distribution among human and artificial agents can radically change the behavior of the distributed system, the behavior of a distributed system should be described by the information flow dynamics [47].

HCDID comprises two related parts: the first part includes multiple levels of analysis for single user human-centered design (user, functional, representational, and task analysis); the second part is dedicated to additional analysis for designing distributed human-centered systems. We did not intend to design a distributed VRET system; therefore we only considered the first part of HCDID.

From our perspective, a human-centered design for software must care about people's feelings, emotions, ideals, aspirations, needs, habits and motivations. Medical software strongly requires considering human emotions, so our methodology takes care of it.

5 A Human-Centered VRET System Design Methodology

VRET systems comprise various technologies: VR, AR and ML. Related to VR, Jerald noted in his book that We must create VR experiences with both emotion and logic [47]. In our methodology for Human-Centered VRET (HCVRET) systems development (Fig. 1), we use a layers-based analysis adopted from the HCDID model and from the NADI model of van der Bijl-Brouwer and Dorst [9]. For the HCVRET implementation, we consider the dimensional model of emotions.

The layers-based analysis for designing a human-centered VRET system comprises 4 levels. Level 1 is dedicated to the users' analysis: patients and therapists, goals and theme analysis. Users' patterns and features of these patterns are identified at this stage. It is important to know their medical history, motivation, education, data about the phobia condition. We are interested in the gaming and computer abilities of the patients, as our intention is to develop a game-based VRET system. The therapists also use the system. They supervise the therapy and can intervene during the game. Also, we need a clear statement of the goals and themes. The goals are formulated in terms of improving the patients' condition and the theme underlying the goals is comfort. Level 1 provides information to the following levels. Level 2 deals with the system analysis requirements, emotion models and knowledge about the mental illness. All information is modeled and encoded to be computationally processed. The VRET system contains a series of tasks which are undertaken by the patients in the therapy. All tasks and subtasks are analyzed at Level 3. Each task has a hierarchical structure: high level tasks related to a goal and subtasks related to sub-goals. Also, there are defined the tasks performed by the therapists: for example, the task of setting the next game level in the therapy. The patients, the therapists and the machines need to communicate in a simple and efficient way. Task analysis involves defining the work procedures. An example of procedure is: the patient plays no more than 15 min followed by a relaxation period of 10 min. In this way, the game-based VRET system is designed to be adaptable to the model of the patient. At Level 4, we identify the patients' and therapists' preferences for colors or sounds, for a certain game, for urban or natural landscapes, for certain technologies and so on. All the information acquired at this stage is used for implementing the VRET system.

We could not find a general methodology for designing virtual reality-based medical software. The proposed methodology is dedicated to this type of application

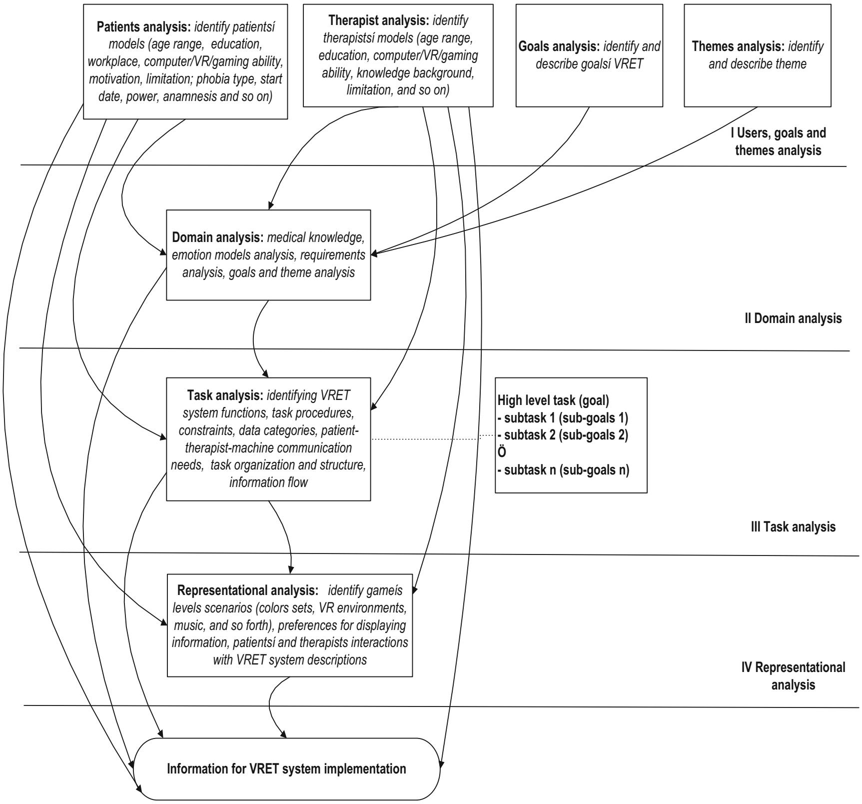

Fig. 1. Layers-based analysis for designing a human-centered VRET systems

and combines human-based product design strategies with medical software design strategies.

6 Case Study: Development of a VRET System for Acrophobia Treatment

6.1 Software Architecture

In this chapter we present the development of a VRET system for treating acrophobia. Our virtual environment is rendered via HTC Vive and depicts a natural setting (a mountain scene with hills and valleys, peaks, forests, a lake, river, transparent platform above a canyon and a transparent bridge) during daytime. The VR environment has been developed using the C# programming language and the Unity graphics engine. The software architecture is composed of the following modules:

Users Manager (Fig. 2) – manages the patients, being dedicated to the therapist. New patients can be added to the system and information about them introduced – name, age, height, sex. Also, each patient selects at this stage his favorite song/picture/quote, which will be presented during the virtual exposure whenever he considers that he needs to relax and calm down. This module also manages existing users, replays sessions and allows the therapist to see statistics concerning the patients' performance. The Users Manager module is connected to a SQL database that stores all the participants' data.

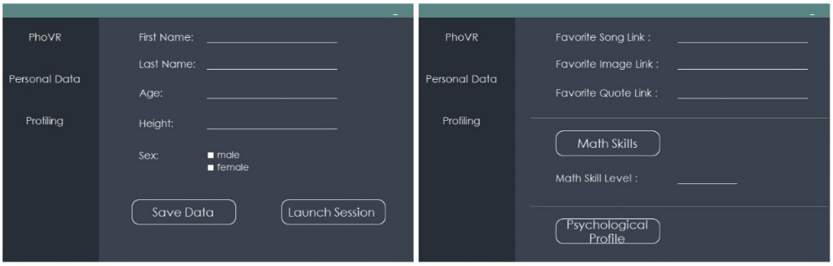

Fig. 2. Users Manager interface

Resources Manager - loads and caches all resources needed at runtime (the patient's profile, scenes, game objects, assets, etc.).

Graphics Manager – ensures graphics rendering and processing, input & output windows and UI (User Interface) display.

Input Manager – manages user input from the HTC Vive controllers. The patient interacts with the virtual environment – displacement, objects selection, menu selection, buttons pressing via the HTC Vive controllers.

Audio Manager – audio rendering management: environmental soundscapes (birds chirping, the sound of the wind), auditory icons when the user selects something from the menu, enters or exits the game, audio cues, plays the user's favorite music clip whenever he needs to relax and take a break from the virtual exposure.

Scenes Manager – manages the scenes (Fig. 3). The user can select any of the following 3 scenes: a ride by cable car a ride by ski lift and a walk by foot. Throughout any of these routes, there are 10 stop points where a mathematical quiz is applied in order to detach the patient from the virtual exposure, deactivate the right brain hemisphere responsible with emotional processing and activate the left one which manages logical and rational responses. After the user correctly answers the mathematical question (Fig. 4), he is required to select his valence, arousal and dominance levels using Self-Assessment Manikins. If he does not correctly answer the current mathematical question, another one appears on the screen and the process is repeated. At the end of the route, the user is returned to the main menu to select another ride, if he wants. At each moment of time, he can stop the cable car or ski lift from moving, as well as to get down and return to the main menu. At any time, the user can choose to take a pause to relax and listen to his favorite piece of music, see a photo depicting something he enjoys and read his favorite quote.

Physiological Monitoring Module – records physiological data (heart rate (HR) and galvanic skin response GSR)). High HR and increased GSR (skin conductivity) are associated with anxiety and fear. Both the user and the therapist can visualize and

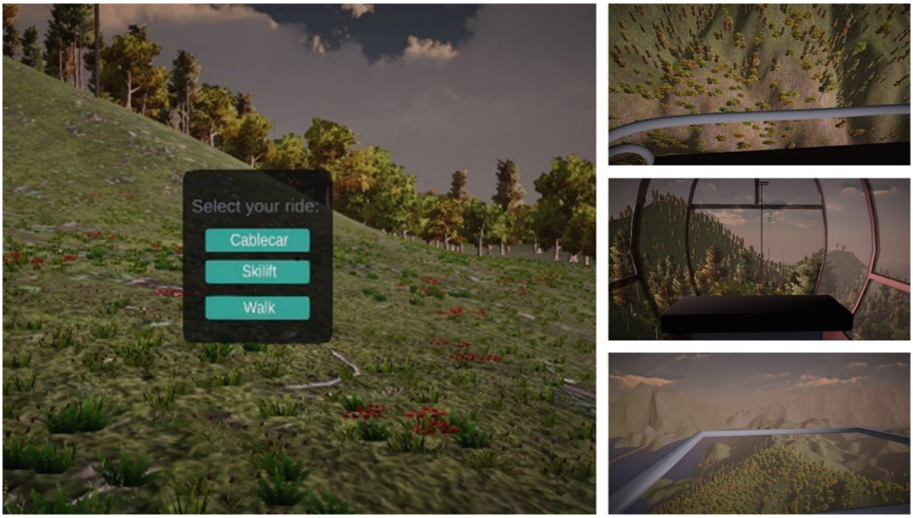

Fig. 3. Game scenarios

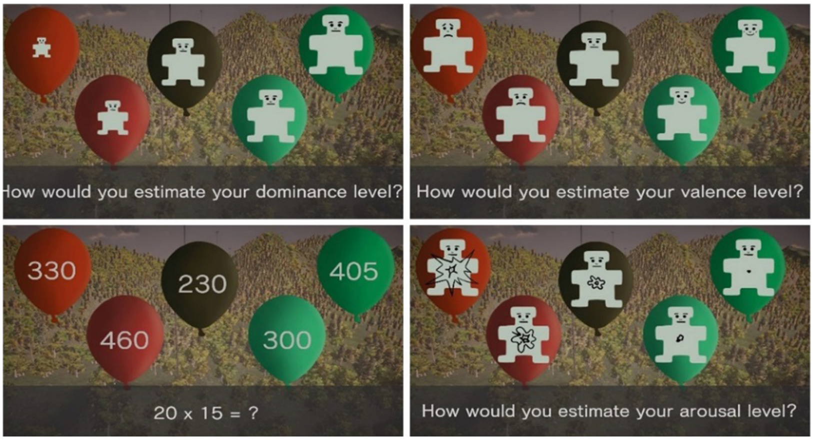

Fig. 4. Applied questions

monitor these parameters and the therapist can also modify the patient's exposure level whenever he considers that the biophysical signals exceeded a critical threshold.

Event System Module - triggers various actions during gameplay like saving statistics, recording valence/arousal/dominance rates, rendering events, animation events and any kind of communication between completely various modules or game objects.

Game Manager – integrates and operates all the modules mentioned above.

The software architecture is presented in Fig. 5.

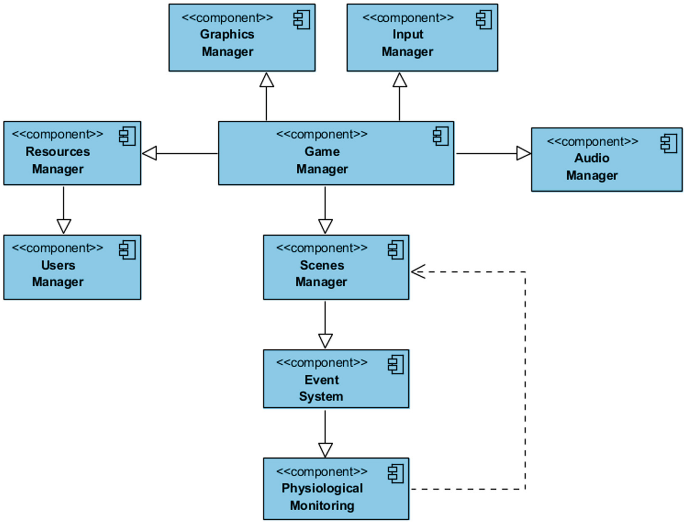

Fig. 5. Acrophobia VRET system software architecture

6.2 Development Methodology

In this section we present the detailed steps of our development methodology for the acrophobia VRET system we propose.

Level I – Users, Goals and Themes Analysis

At this stage, we identified the goal and theme: the goals refer to improving the patients' phobia-related conditions and the themes represent the comfort and safety. So, our main concern was to achieve the goals that ensure patients' comfort during the game.

Also, we identified the patients' and therapists' profiles, as well as what they expect from the system. The patients expect an immersive virtual environment, with a high level of realism, accessible tasks and a diverse range of in-game activities. For this, we developed the Scenes Manager module with increased attention to details in order to ensure a high level of immersion. All the 3 scenes – cable car, ski lift and walking route are carefully designed, having their graphics adapted to be rendered via the HTC Vive glasses. The input modality is also accessible and easy to be used. Thus, the patient interacts with the environment by pressing a few buttons from the Vive controller to teleport himself in the scene, select his responses to the mathematical questions and introduce the valence/arousal/dominance ratings, start, stop or exit the game, select the preferred scenario. The patients are however reluctant towards heavy and uncomfortable biophysical equipment. Thus, even if at the beginning of our research we pursued the idea of recording EEG data, we finally dropped it out and kept only GSR and HR. These biophysical signals have been recorded using the Shimmers Multisensory device which has integrated compatibility with the C# programming language through its API [48]. The therapists expect a reliable system, with a high level and realism and immersion, visualization of what the patient is seeing in the virtual environment, as well as of his biophysical signals, so that they can easily adapt the exposure scenario. In addition, they want to have access to recordings of the users' performance in order to calculate statistics and perform post-therapy analyses. To accomplish these requests, we developed the Physiological Monitoring module and the Users Management module.

Level II – Domain Analysis

At this stage of development, we interacted with psychologists and psychotherapists, in order to understand the emotional profile of the people suffering from acrophobia. Here we researched the domain of affective computing and defined fear as an emotion with low valence, high arousal and low dominance. The psychologists advised us to repeatedly ask the patients for their self-reported valence, arousal and dominance ratings, but before it is recommendable to detach them from the current intense emotional state, deactivate the right hemisphere and activate the left one by applying some mathematical quizzes. By listening to his favorite piece of music, look at a picture or read his preferred quotation, the patient also achieves a high state of relaxation, being at the same time an effective self-reward solution. The person rewards himself from time to time after experiencing a stressful situation or expecting to reach a certain game level, so that he can take a break, stop the exposure temporarily and enjoy a short, but pleasant activity. The data collected (biophysical signals and valence/arousal/dominance ratings) will be further used for designing an additional module, called Fear Estimation. Several machine and deep learning techniques will be used to construct a model that automatically determines the patient's current level of fear, so that the therapist will know not only the biophysical raw values, but also whether the user experiences low/medium/high fear. In this way, he can adapt the exposure scenarios more easily. Future plans include the development of an Automatic Exposure Adaptation module, where, based on the knowledge collected from the therapist, the patients' biophysical data and fear level estimation, a virtual therapist will adapt the level of exposure automatically, without or with minimum intervention from the human expert. In addition, in our future research, we intend to integrate a form of neurofeedback, so that the elements from the virtual environment would change their appearance according to the user's emotional state. So, the sky can become cloudier or darker when the patient feels anxious, clearer when he is calm and change dynamically during the session. By being provided with this form of feedback, the patient can struggle to relax and induce himself a state of relaxation in order to change the appearance of the natural elements from the virtual environment.

Level III – Task Analysis

Here we identified the tasks and corresponding subtasks. The user can select at the beginning the route he wants to take – a ride by cable car, ski lift or a walk by foot. Throughout any of these routes, there are 10 stop points where a mathematical quiz is applied. After the user correctly answers the mathematical question, he is required to select his valence, arousal and dominance levels using Self-Assessment Manikins. We established the interaction between the human and the machine, communication protocols, user interfaces. All the system's tasks – patients management, virtual exposure management, physiological monitoring, application logic, flow control – have been designed and implemented at this step.

Level IV – Representational Analysis

Here we established which will be the virtual scenarios, with both their graphical and audio components. Such, we designed a landscape with forests, cliffs, canyons, peaks, a cable car, a ski lift, a transparent platform and all the visual elements. As audio elements, we can mention the sound of bird chirping and the wind. At this stage of research, we have only one virtual setting, i.e. the mountain, but very shortly we will develop a cityscape with tall buildings, glass elevators, terraces and balconies.

The experimental procedure has the following steps:

- The user is informed about the purpose of the experiment and signs a consent form, a demographic questionnaire and an acrophobia questionnaire. Based on the acrophobia questionnaires, the subjects will be divided into 3 groups – low acrophobia, medium acrophobia and high acrophobia. He also fills in a mathematical questionnaire, based on which we will determine the math skills level – Novice, Medium or Expert
- We record GSR and HR in a resting position for 3 min (baseline).
- We record GSR and HR while the user performs some short movements that can cause artefacts in the signal – deep breath, left, right, up and down movement, hand raise and click on the controller with the right hand. Having the pattern of these artefacts, we can clear the signal and remove irregularities that interfere with the physiological data recorded during the game and which are not related to emotions.
- The user will play the game three times per day, for 5 days, in this order: walking, ski lift and cable car. At the end of each day, he fills in a game experience questionnaire.
- Finally, at the end of the training session, each user will fill in again the acrophobia questionnaire to see whether his acrophobic condition has improved
- The data recorded in the experiment will be used to train an artificial intelligence model that will automatically estimate fear level and adapt the game scenarios accordingly

7 Conclusions

This paper presented a human-centered methodology inspired from the HCDID model and from the NADI model of van der Bijl-Brouwer and Dorst [9] for designing and developing a VRET system. The four stages of development – Users, goals and themes analysis, Domain analysis, Tasks analysis and Representational analysis have been adapted for the development of a VRET application dedicated to acrophobia therapy. We have carefully followed these steps and, by taking into account the patients' and therapists' requirements in a human-centered fashion, succeeded to obtain 9 functional modules responsible with users management, physiological monitoring, event triggering and audio & graphical management. The human-centered perspective is ensured by the virtual environment's level of realism and real life inspired tasks, the first person perspective in the game that is adapted according to the player's height and by the fact that the scenario is receptive to the user's needs, so that he can relax anytime by looking at his favorite photo, listen to his favorite piece of music or read a quote he enjoys. This system of rewards is not only encouraging, but also motivating and pleasurable. We payed attention to the modality in which the user provides his emotion dimension ratings. At a psychologist suggestion, we provided a modality of deactivating the right cortical hemisphere responsible with affect and activate the left one that is responsible with thought and logic. Thus, the user is asked a mathematical quiz before introducing his emotional ratings. Also, in order to establish the mathematical skills, each user receives a test before starting the virtual reality exposure. Based on the results obtained in this test, he can receive either low difficulty/medium difficulty or high difficulty mathematical questions in the game.

Our system can collect and store data from the patients and from the therapists. This data will be used for constructing a computational model that will automatically recognize the patient's current fear level and adapt the scenario accordingly, without or with minimum intervention from the human specialist.

Future plans include performing a set of experiments with people suffering from acrophobia, collecting data and designing a computational model for emotion recognition and exposure adaptation by using various feature extraction and effective machine learning techniques.

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References

1. Phobias Statistics. http://www.fearof.net/phobia-statistics-and-surprising-facts-about-our-biggest-fears/
2. Olesen, J.: Phobia Statistics and surprising facts about our biggest fears (2015). http://www.fearof.net/phobia-statistics-and-surprising-facts-about-our-biggest-fears/
3. Nation Wide Phobias Statistics. https://blog.nationwide.com/common-phobias-statistics/
4. Acarturk, C., Smit, F., de Graaf, R., van Straten, A., ten Have, M., Cuijpers, P.: Economic costs of social phobia: a population-based study. J. Affect. Disord. **115**, 421–429 (2009)
5. Trautmann, S., Rehm, J., Wittchen, H.-U.: The economic costs of mental disorders. EMBO Rep. **7**, 1245–1249 (2016)
6. Garcia-Palacios, A., Hoffman, H.G., Kwong See, S., Tsai, A., Botella, C.: Redefining therapeutic success with virtual reality exposure therapy. CyberPsychology Behav. **4**(3), 341–348 (2001). https://doi.org/10.1089/109493101300210231
7. Opris, D., Pintea, S., Garcia-Palacios, A., Botella, C., Szamoskozi, S., David, D.: Virtual reality exposure therapy in anxiety disorders: a quantitative meta-analysis. Depress. Anxiety **29**, 85–93 (2012)
8. Zhang, J., Patel, V.L., Johnson, K.A., Malin, J., Smith, J.W.: Designing human-centered distributed information systems. IEEE Intell. Syst. **17**(5), 42–47 (2002)
9. van der Bijl-Brouwer, M., Dorst, K.: Advancing the strategic impact of human-centered design. Des. Stud. **53**, 1–23 (2017). 0142-694X
10. C2Phobia. https://www.c2.care/en/c2phobia-treating-phobias-in-virtual-reality/
11. PSIOUS, https://www.psious.com/

12. Stim Response Virtual Reality. https://www.biopac.com/application/virtual-reality/
13. Virtual Reality Medical Center. https://vrphobia.com/
14. Virtually Better. www.virtuallybetter.com
15. Limbix. https://www.limbix.com/
16. Phobos. https://samsungvr.com/view/Uu9ME9YXR_B
17. The Climb. http://www.theclimbgame.com/
18. Ritchie's Plank Experience. https://www.viveport.com/apps/9347a360-c6ea-4e35-aaf1-9fab4f41cb79/Richie's_Plank_Experience/
19. Samsung Fearless Cityscapes. https://www.oculus.com/experiences/gear-vr/821606624632569/
20. Samsung Fearless Landscapes. https://www.oculus.com/experiences/gear-vr/1290835750988761/
21. Arachnophobia. https://store.steampowered.com/app/485270/Arachnophobia/
22. Limelight. https://store.steampowered.com/app/544880/Limelight_VR/
23. Activity. https://www.unitylab.de/
24. Coelho, C.M., Silva, C.F., Santos, J.A., Tichon, J., Wallis, G.: Contrasting the effectiveness and efficiency of virtual reality and real environments in the treatment of acrophobia. Psychol. J. **6**(2), 203–216 (2008)
25. Emmelkamp, P.M., Krijn, M., Hulsbosch, A.M., de Vries, S., Schuemie, M.J., van der Mast, C.A.: Virtual reality treatment versus exposure in vivo: A comparative evaluation in acrophobia. Behav. Res. Ther. **40**, 509–516 (2002)
26. Izard, C.E.: The emotions and emotional constructs in personality and culture research. In: Cattel, R.B. (ed.) Handbook of Modern Personality Theory. Aldine, Chicago (1969)
27. Ekman, P., Cordaro, D.: What is meant by calling emotions basic. Emot. Rev. **3**(4), 364–370 (2011)
28. Hockenbury, D.H., Hockenbury, S.E.: Discovering Psychology. Worth Publishers, New York (2007)
29. Cabanac, M.: What is emotion? Behav. Process. **60**, 69–84 (2002)
30. Ekman, P., Friesen, W.V.: Constants across cultures in the face and emotion. J. Personal. Soc. Psychol. **17**, 124–129 (1971)
31. Russell, J.A.: A circumplex model of affect. J. Pers. Soc. Psychol. **39**, 1161–1178 (1980)
32. Posner, J., Russell, J.A., Peterson, B.S.: The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. Dev. Psychopathol. **17**(3), 715–734 (2005)
33. Mauss, I.B., Robinson, M.D.: Measures of emotion: a review. Cogn. Emot. **23**(2), 209–237 (2009)
34. Plutchik, R.: Emotion: theory, research, and experience. In: Theories of Emotion, vol. 1. Academic, New York (1980)
35. Sacharin, V., Schlegel, K., Scherer, K.R.: Geneva Emotion Wheel Rating Study (Report). University of Geneva, Swiss Center for Affective Sciences, Geneva (2002)
36. The Geneva Emotion Wheel. https://www.unige.ch/cisa/gew/
37. Uhrig, M.K., Trautmann, N., Baumgärtner, U., Treede, R.D., Henrich, F., Hiller, W., Marschall, S.: Emotion elicitation: a comparison of pictures and films. Front. Psychol. **7**, 180 (2016)
38. Lang, P.J., Bradley, M.M., Cuthbert, B.N.: International Affective Picture System (IAPS): affective ratings of pictures and instruction manual. Technical Report A-6. Gainesville, FL: University of Florida (2005)
39. Masood, N., Farooq, H.: Investigating EEG patterns for dual-stimuli induced human fear emotional state, Sensors (2019)
40. Ekman, P.: A methodological discussion of nonverbal behaviour. J. Psychol. **43**, 141–149 (1957)

41. Reitano, N.: Digital emotions: the potential and issues of affective computing systems. M.Sc. Interactive Digital Media (2018)
42. Huang, T., Jones, P., Kasif, S.: Human centered Systems: information, interactivity, and intelligence. Report, NSF (1997)
43. Jaimes, A., Sebe, N., Gatica-Perez, D.: Human-centered computing: a multimedia perspective. In: Proceedings of the 14th ACM International Conference on Multimedia (MM 2006), pp. 855–864. ACM, New York (2006)
44. Gillies, M., Fiebrink, R., Tanaka, A., Garcia, J., Bevilacqua, F., Heloir, A., Nunnari, F., Mackay, W., Amershi, S., Lee, B., d'Alessandro, N., Tilmanne, J., Kulesza, T., Caramiaux, B.: Human-centered machine learning. In: Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA 2016), pp. 3558–3565. ACM, New York (2016)
45. Seffah, A., Andreevskaia, A.: Empowering software engineers in human-centered design. In: Proceedings of the 25th International Conference on Software Engineering (ICSE 2003), pp. 653–658. IEEE Computer Society, Washington, DC (2003)
46. Seffah A., Gulliksen J., Desmarais M.C.: An introduction to human-centered software engineering. In: Seffah, A., Gulliksen, J., Desmarais, M.C. (eds) Human-Centered Software Engineering — Integrating Usability in the Software Development Lifecycle. Human-Computer Interaction Series, vol 8. Springer, Dordrecht (2005)
47. Jerald, J.: The VR Book: Human-Centered Design for Virtual Reality. ACM (2016)
48. Shimmer Sensing. http://www.shimmersensing.com/