Full Body Immersive Virtual Reality System with Motion Recognition Camera Targeting the Treatment of Spider Phobia

Jacob Kritikos[1(✉)], Stavroula Poulopoulou[2], Chara Zoitaki[3], Marilina Douloudi[4], and Dimitris Koutsouris[1]

[1] Biomedical Engineering Laboratory, National Technical University of Athens, 15780 Athens, Greece
{jkritikos,dkoutsou}@biomed.ntua.gr

[2] Department of Digital Systems, University of Piraeus, 18534 Piraeus, Greece
stavroula.plplou2@gmail.com

[3] School of Electrical and Computer Engineering, National Technical University of Athens, 15780 Athens, Greece
charazoitaki@gmail.com

[4] Department of Biology, National Kapodistrian University of Athens, 15780 Athens, Greece
marilina.douloudi@gmail.com

Abstract. Exposure Therapy (ET) is one of the most widely-used methods for treating Specific Phobias, and, over the past few years, Virtual Reality (VR) has contributed significantly in this field, since the birth of what we call "Virtual Reality ET" (VRET). However, VR systems used in VRET so far do not fully integrate ET characteristics; the reason behind this is that they do not provide sufficient, or occasionally not any at all, interaction with the feared stimulus, which is a key factor for full ET implementation. Objective: The aim of our study is to propose a way to include natural interaction between the patient and the system during the treatment procedure. Method: We propose an addition to current session protocols for mental health professionals through which they can apply ET in full extent with the use of motion tracking sensors. Specifically, we added a Motion Recognition Camera, which tracks the patient's movements and places their physical body within the virtual environment, increasing their feeling of presence and making the system more immersive. Therefore, clinicians can assign interactive tasks for their patients to practice within a controlled virtual environment. Results: We present the feedback we received regarding the system's potential utility and efficiency by a group of psychiatry professionals who tried the system. Impact: With real-time interaction and VRET, patients stand a better chance to truly acquire the necessary skills to overcome their phobias.

Keywords: Virtual reality · Cognitive behavioral treatments · Exposure therapy · Anxiety disorders · Specific phobias · Motion tracking sensor · Motion recognition camera · Presence · Clinical treatment · Immersion

P. Cipresso et al. (Eds.): MindCare 2019, LNICST 288, pp. 216–230, 2019.
https://doi.org/10.1007/978-3-030-25872-6_18

1 Introduction

Anxiety disorders share features of excessive worry and fear that cause behavioral disturbances to the suffering individuals. Approximately 1 in 5 adults will manifest some form of Anxiety Disorder at some point in their lives with rates being twice as high for minors [1–4]. Specific phobias are a type of anxiety disorder defined as the persistent fear of a stimulus, potentially an object or a situation, which renders the person unable to demonstrate self-control. Specific phobias along with agoraphobia and social phobia are one of the most common types of phobias, which in fact are considered as sub-types of a broader category, that of anxiety disorders, according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V). According to the American Psychiatric Association [1], the lifetime prevalence of specific phobias is approximately 7%–9% in the US and 6% in Europe, and can reach up to 12,5% [5]. Although a lot of research has been conducted in this field over the past few years, only a minority (8%) of people reported with specific phobias have received any treatment [6, 7].

The most well-known treatment of various cognitive and behavioral disorders is Cognitive Behavioral Therapy (CBT) [8, 9], since it appears as the preferred method by the majority of mental health professionals to treat phobias; this may be due to the fact that a number of scientists claim CBT has no possible side-effects, unlike medication [1, 10]. The basic principles of CBT focus on identifying, understanding and altering patients' thought and behavioral patterns. Patients are actively involved in their own recovery, which offers them a stronger sense of control; additionally, through therapy sessions, they obtain useful skills they ought to practice repeatedly in order to present the desirable progress [11].

The applications of CBT, along with its different forms, have been highly efficient so far; by evaluating previous studies, we can deduce that an average of 50% of patients managed to decrease their phobia-related anxiety [12–17]. Nonetheless, certain studies reviewing CBT results [18, 19] indicate that it is still unclear whether the phobia returns after a short period of time or not. For instance, a recent research [20] claims that the phobia does not return at least amid the first semester. Yet, some scientists disclose that CBT's benefits do not necessarily last long; specifically, another study [21] mentions that results lasted only for the first 20 days.

Exposure Therapy (ET) is a form of CBT treatment [22] developed to help people confront their fears in a safe environment. There are several variations of ETs, such as 'In VIVO ET', 'Virtual Reality ET' (VRET) [23], 'Imaginary ET' and 'Interoceptive ET' ([23, 24] but all of them follow the same basic procedure [25–27], which usually consists of the following steps:

Step 1: The cognitive sessions, where the patient is informed about their condition and their unreasonable thought patterns; next, the patient discusses any existent distressing thoughts and possible dreaded scenarios with the experts.

Step 2: The exposure sessions, where the patient is exposed to assorted phobic situations with graded difficulty through In VIVO ET or VRET. This step is repeated until the patient's anxiety levels decrease.

Step 3: The follow-up sessions appointed after a significant period of time in which clinicians evaluate the overall decrease in the patient's anxiety levels.

During In VIVO ET, patients are asked to confront the feared stimulus in real life. However, simulating every possible scenario in real life is expensive and time-consuming; for instance, in case a patient is suffering from aviophobia, they would have to buy an airplane ticket and go through the entire boarding process accompanied by their clinician, who usually charges by the hour [28, 29]. Also, in some cases, it could lead to undesired results since displeasing occurrences may further terrorize patients (e.g. turbulence during the flight in the early stages of ET [30]). In order to overcome such technical issues, VRET is starting to replace In VIVO ET.

In VRET, patients are exposed to virtual, life-like, anxiety-provoking environments instead of real stimuli [31–33]. Within them, they can practice tasks assigned by their clinician in a controllable, and therefore safe, virtual environment designed to appropriately stimulate their specific phobia, in the clinician's office. Due to that, patients feel more comfortable and confident; thus, they are more willing to confront situations that cause them discomfort and explore alternative ways of responding. Also, even though their actions occur in the virtual world, the knowledge acquired transfers to the real world [34]. Lastly, over the last few years, studies have found VRET to be as effective as In VIVO [31] in terms of triggering anxiety. Therefore, treatment through VR systems could become a low-cost method of providing effective interventions at scale.

Overall, we can conclude that ET has two primary characteristics: [a] patients have to come in contact with the feared stimulus actively, and [b] patients have to master how to confront and respond to said stimuli without fear or anxiety. Current VRET applications provide contact with the feared stimulus, i.e. trigger fear through VR videos; however, they have not yet been able to allow patients to interact actively with the stimulus. At best, the only interaction that is currently available is via hand controllers through which complex tasks and exercises, such as touching and moving objects with the rest of their body (e.g. their feet) cannot be completed, due to the nature of hand controllers' design that only provides hand interaction. Therefore, certain scenarios cannot be simulated. Overall, VRET has managed to stimulate patients' anxiety through a virtual stimulus; yet, patients usually remain passive or interact poorly, which doesn't improve immersion, and consequently, the patient's feeling of presence in the virtual environment is decreased. Hence, in order for VRET to reach its full potential and implement ET as a whole, life-like interaction must be added to existing systems [31, 35, 36].

In this study, we present and propose a fully immersive VR System by adding a new tool, the Motion Recognition Camera (MRC), on top of the VR technology. The MRC tracks patients' movements, places their physical body within the virtual environment and gives them the impression that they are moving and interacting in full extent with that environment, as they would in the real world. This allows patients to practice tasks whilst in the virtual environment. By combining these technologies, we increase the user's immersion and presence. Additionally, we propose that Step 2 be separated into two different cycles regarding the exposure sessions: [a] Step 2-a in which VRET is applied as it currently is; patients come in contact with the phobic stimulus for the first time in a controlled environment and learn how to stay close to the stimulus without losing their composure, and [b] Step 2-b in which patients practice possible coping mechanisms, that differ from the ones originated from physical environment, like concepts of avoidance and fear anticipation [37] by directly interacting with the phobic stimulus, and by learning to control their reaction and regulate their anxiety response. In this study, we define Step 2-b as "Action Therapy", to emphasize the importance of confrontation, which needs to become a separate and independent part of the sessions.

So, our hypothesis is whether the proposed system can provide appropriate interaction and confrontation with the phobic stimulus, which could improve current treatments in the future. We examined this hypothesis through a trial-run, with the medical staff of a psychiatric clinic as participants. After completing the study, the clinicians gave us their professional feedback on their experience with the proposed system as well as suggestions for its further improvement.

2 Materials

2.1 Hardware

The proposed system consists of the following equipment: [a] VR Goggles (VRG): "Gear VR" by Samsung; [b] a Mobile Phone: the "Galaxy S7" by Samsung; [c] a Motion Recognition Camera (MRC): the "Astra S" by ORBBEC; the specifications of the MRC are: Range: 0.6–8.0 m (Optimal 0.6–5.0 m), Depth Image Size: 640*480–30fps, RGB Image Size: 1280*960–30fps, Field of View: 60° horiz. x 49.5° vert. (73° diagonal). The MRC tracks the patient's movements, places their physical body in the virtual environment and gives them the impression that they are moving and interacting with their whole body in that environment in real time, as they would in the real world. This allows the patient to practice tasks assigned by their clinician in the virtual environment; [d] a Windows Desktop Computer.

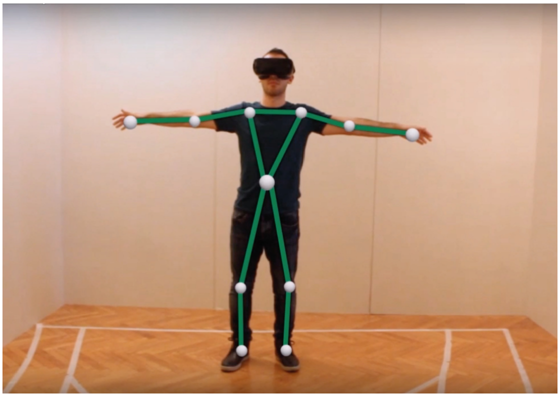

Fig. 1. The MRC is installed in front of the user to recognize the joints and place them inside the virtual environment.

2.2 Software

We created a C++ program and used the Orbbec Astra SDK, along with the Bluetooth Windows SDK, to assist us in body recognition and its dispatching from the Desktop Computer, which operates the MCR, to the Gear VR. Android Studio was used to create the Bluetooth receiver program; Unity 3D was used for creating the virtual environment depicted by the VRG; Blender 3D Computer Graphics was used for creating 3D objects, animated visual effects and materials, and Adobe Photoshop for designing images for the materials. Moreover, regarding the body tracking software, the Astra S MRC is designed for skeleton tracking (Fig. 1); consequently, it can recognize the entire body and movements of its limbs. The program we have written for the MRC tracks the joints (Fig. 2); then, the user's skeleton is represented in the virtual room as a set of spheres and lines (the spheres represent the joints and the lines represent the bones connecting joints).

2.3 System Setup

The outlined area is about 5 m^2 and will be referred to as the "Action Area". In the Action Area, the user wears the VRG and is able to observe the virtual environment. The user does not need to wear or hold any other equipment than the VRG, in order to move and interact with objects. The MRC is placed on a table at a 1 m distance from the Action Area, so as to record the user's movements and transfer them to the virtual environment.

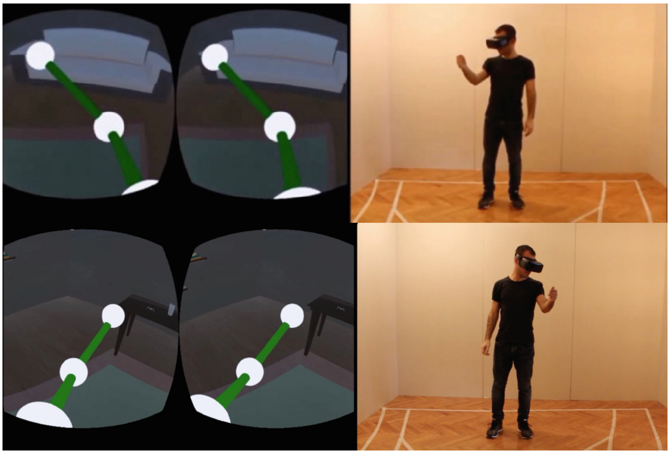

Fig. 2. Users can see their skeleton inside the virtual room. Top: The user's right arm. Bottom: The user's left arm.

3 Method

The proposed system was tested by twenty members of the Psychiatry Department of the Oncological Hospital of Kifisia staff (doctors, professors, nursing staff and the hospital's general manager), in Athens, Greece. All of the participants were familiar with the concept of using visual cues before (pictures, videos, standalone VR) as an effective way to stimulate fear emotions to phobic or non-phobic subjects. The aim of the session was for all participants to use the proposed system and answer a small questionnaire about their experience with it.

Q1: Do you believe that Exposure Therapy could benefit from the addition of interaction?

NO	MAYBE-NO	MAYBE	MAYBE-YES	YES

Q2: Do you think that interaction with the Motion Recognition Camera in the Virtual Environment can give real life experience?

NO	MAYBE-NO	MAYBE	MAYBE-YES	YES

Q3: Do you believe that coping mechanisms learnt in virtual situations and environments can be transferred to real-life situations?

NO	MAYBE-NO	MAYBE	MAYBE-YES	YES

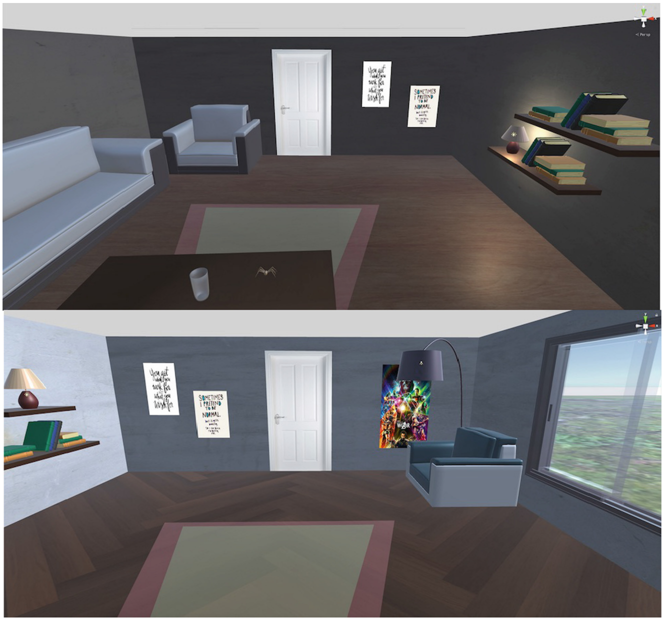

Fig. 3. Top: The virtual room of Level 1. Bottom: The virtual room of Level 2.

Furthermore, we present an implementation of Action Therapy. Spider phobia was used as a case study. The procedure consisted of one session with two levels of difficulty. During this session, two tasks were assigned to participants, aiming to help them in mastering new coping mechanisms, so as to confront their phobia, habituate with the phobic environment and eventually interact with the stimulus while remaining under control.

Level 1

Step 1: The user enters the Action Area, while the MRC is located at a 1 m distance. This is the area where the user can walk, move and react to the stimuli. *Step 2:* The user wears the VRG and enters the virtual environment (Fig. 3). *Step 3:* In the VR room, the user can observe their virtual arms, as well as walk and touch whatever objects are permitted. *Step 4:* The user reads the perspicuous instruction that appears at the top of the screen. This instruction describes the task the user is expected to fulfill in the level. Level 1 opening instruction: "Try to approach the spider" (Fig. 4). *Step 5:* The user performs the requested task. The aim of the first (easy) level is to allow users to observe the phobic object, to familiarize with it and thus exercise their response and composure when it appears in their personal space. In Level 1, the user must: [a] observe the virtual room: this helps users feel comfortable in the realm of the virtual environment, move more confidently in it and realize that their physical movements control their virtual ones in real time; [b] approach the spider in their own time whilst keeping their composure: the user can walk towards the table, where a white spider stands still; they can approach the spider whenever they feel ready and confident in themselves. The spider does not move at all, which gives users confidence and a strong sense of control. *Step 6:* The user reads the final instruction that appears at the top of the screen. This instruction congratulates them on successfully completing the task and marks the end of the first level. Level 1 final message: "Congratulations!" (Fig. 4). A demonstration video of the system is available here: youtube.com/watch?v =Fcj9uE_wv0I.

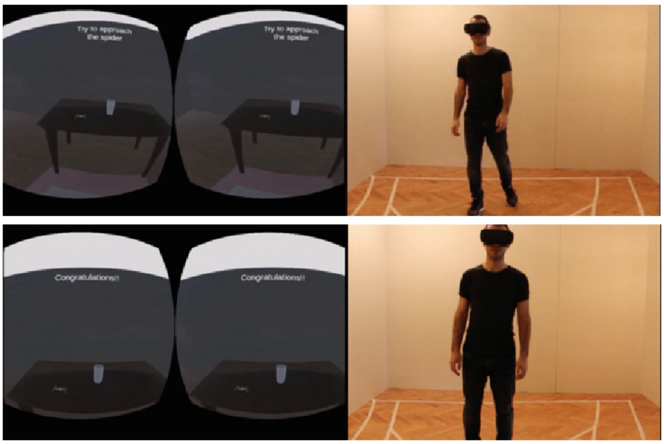

Fig. 4. Level 1: Top: The user's first goal is to try to approach the spider. Bottom: Once the user has managed to get close, the assignment is considered completed.

Level 2

Step 1: The user remains in the Action Area without taking the VRG off, since Level 2 starts automatically once Level 1 is completed. Step 2: The user enters a new virtual room. Step 3: The user reads the perspicuous instruction that appears at the top of the screen. This instruction describes the task the user is expected to complete during the level. Level 2 opening instruction: "Try hitting the spider 3 times". (Fig. 5) Step 4: The user performs the requested task. The aim of the second (hard) level is to allow users to touch the stimulus and learn how to remain calm, as well as confront the spider when it appears in their personal space. In Level 2 the user must: [a] approach the spider in their own time whilst keeping their composure: in this level, a black spider is hanging from the ceiling using its web, which gives it the ability to swing whenever the user hits it. The user can walk toward the spider when they feel ready and confident in themselves. The spider does not move unless the user hits it; this gives them time to relax and realize that the spider will not approach them unexpectedly; therefore, they have full control of the situation; [b] the user is requested to hit the spider three times and manage to stay close; the width of the spider's swing depends on the power of each hit, which increases the user's sense of control. They have to repeat the same action three times, so as to gradually realize that the spider cannot truly hurt them but instead, they can repel it if they want to; the user can even move a step back whenever the spider swings towards them; yet, it is crucial that they keep their composure and continue until they complete the task (Fig. 5). Step 5: After completing the task, the user reads the final instruction that appears at the top of the screen. This instruction congratulates them on successfully completing the task and marks the end of the second level: "Congratulations!". A demonstration video is available here: youtube.com/watch?v = qDBbSoOrUKY.

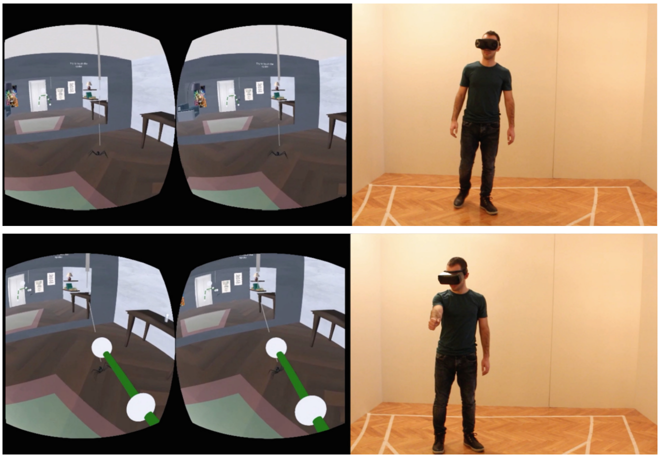

Fig. 5. Level 2: Top: The user sees a spider hanging from its web. Then, the instruction appears: "Try hitting the spider 3 times". Bottom: The user hits the spider.

4 Results

As we can see in Fig. 6, the clinicians reportedly mentioned that action is crucial for treating specific phobias, since 80% answered “MAYBE YES” or “YES”. In Fig. 7, we can see that 80% of them answered “YES” or “MAYBE YES” to whether they think that the proposed system with MRC interaction can simulate real-life experiences. Last but not least, in Fig. 8, we can see a reduction of positive results, since 50% of the participating clinicians answered “MAYBE YES” or “YES” to whether coping mechanisms acquired in a virtual environment can be transferred to the real world. Only 2 out of 20 answered “YES”.

Thereby, we conclude that not only is interaction necessary for the treatment process but also that the proposed system can simulate an appropriate interaction between the stimulus and the user through the VR simulation; however, according to the 20 clinicians, it is yet unclear whether virtual reality can actually assist patients in real life, despite the full body interaction.

Overall, the participants were initially thrilled with the opportunity to interact with the virtual environment. What was particularly interesting is that participants completed their task easily in the first level, where they were not asked to interact with the spider; nonetheless, during level 2, where participants were expected to interact with the stimulus, they were amazed by the possibility of interacting with the spider in such a straightforward way. Due to that, we can deduce that interaction with the feared object in the spectrum of a virtual environment could be far more efficient than the sole habituation of patients’ anxiety through vivid virtual representations of the stimulus, i.e. images and videos. Also, even though participants were not familiar with the technology of the proposed system, no issues emerged during the simulations (Fig. 9).

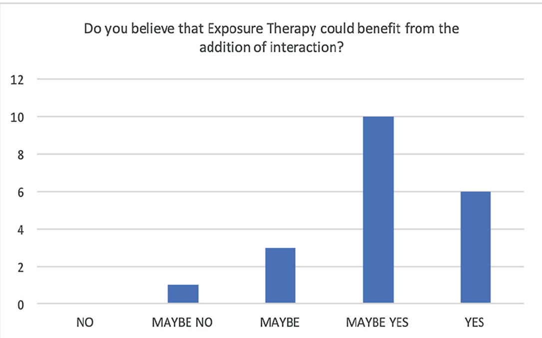

Fig. 6. The answers from the question Q1: “Do you believe that exposure therapy could benefit from the addition of interaction?”.

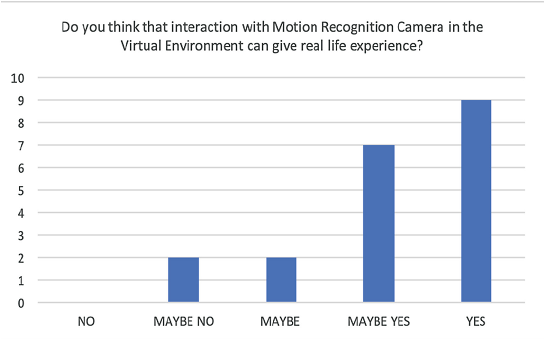

Fig. 7. The answers from the question Q2: "Do you think that interaction with the motion recognition camera in the virtual environment can give real life experience?".

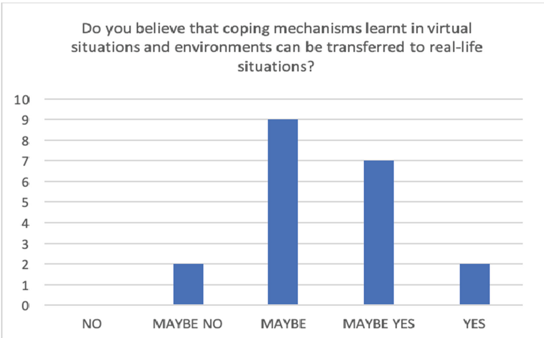

Fig. 8. The answers from the question Q3: "Do you believe that coping mechanisms learnt in virtual situations and environments can be transferred to real-life situations?".

5 Discussion

The present study investigated the possibility of expanding current ET treatments by adding another step, a new cycle of sessions in the procedure-, the one we refer to as "Action Therapy". The main intention of that step is to complement the visual stimuli already used in VRET by enhancing the confrontational capabilities of the patient towards their phobia during the treatment process. Our hypothesis is that the experience patients gain through the VR simulation could be more constructive and contribute significantly to their progress.

Thus, to determine whether the proposed Action Therapy could improve ET and be helpful to patients, we tested the proposed system on a group of 20 people consisting of professionals in the field of psychiatry. The aim of this trial was to introduce them to the system and, based on their experience, get their feedback on whether or not it could be beneficial for patients and add to their training.

Our hypothesis has been confirmed to a large extent since the majority of clinicians found the addition of action to the existing treatment procedure promising for patients. However, they presented their doubt whether coping mechanisms acquired during VR could be utilized in real-life; an indication that VR has to further improve to actually assist clinicians in the treatment of mental illnesses.

In spite of the promising feedback we received, there are limitations to take into consideration. Regarding the procedure, the trial was conducted on only a small group of 20 clinicians; therefore, the data was not extensive.

Another issue worthy of discussion is our choice to use the Motion Recognition Camera instead of other motion recognition tools, in order to add interaction to the VR system. Thanks to technological advances, there are various affordable commercial motion tracking devices available, from the motion recognition camera to wearable body tracking sensors, like gloves and suits with gyroscope trackers or accelerometer

Fig. 9. Photos from the system trial-run at the Hospital: *(top)* The participant tries to hit the spider with her punches; *(bottom)* The participant observes her hands in the virtual room.

trackers, and hand controllers. The main reason we did not choose to use hand controllers is because they limit the interaction capability of the patient's body within the virtual environment, thus potentially rendering their movements unnatural, i.e. they have to press certain buttons instead of using their hands, so as to touch objects [38–40]. Regarding other wearable sensors, they would make the system's set up and operation more complicated, only to achieve the same result. Nevertheless, the MRC has some limitations as well, since it cannot track movements in all body parts (e.g. the fingers) due to its tracking range (0.6-8.0 m). However, the purpose of this study was not to extensively examine the differences between different types of motion tracking sensors, but to determine whether full-body interaction, in general, could benefit existing treatment protocols.

Finally, another interesting aspect of our study was that MRCs offer a remarkable feature: the tracking of the patient's physical movements is not only useful for placing their body in the virtual environment, but also for dispatching the information obtained by their movements in real time. Measurements of the patient's movements as they perform the assigned tasks can help draw further conclusions about the patient's performance, i.e. whether the patient completed the task effortlessly or not. This method could even help in the field of diagnostics, by comparing that data to those of healthy individuals.

6 Conclusion

Up to now, there has been no experimental indication stemming from clinical trial results that VRET is more effective than in VIVO ET. Nevertheless, previous studies have found them equally effective for patients. Considering the technical issues of In VIVO ET such as affordability, the time needed to implement it, as well as the fact that it is impossible for clinicians to acquire every phobic stimulus, VRET seems to be at least as helpful as In VIVO ET [41]. Acquisition costs of VR systems have dropped significantly, making it possible for VRET to be applied in a larger scale in clinicians' offices, either in private practice or clinics and hospitals.

Following, we propose that biomedical laboratories and tech-oriented research centers focus more on technologies that fit the needs of anxiety disorder field. Overall, VR applications related to anxiety disorders are still on an early stage of development, without any solid foundations built yet. Currently, this field seeks to adapt itself to the newly introduced technological tools [42–45]. At the same time, the technological tools themselves, also need to adapt to the respective safety regulations [30]. Our aim, through our research, focuses on encouraging the creation of systems precisely for the needs of this industry.

Finally, we suggest the proposed system could be an effective tool in other areas. By modifying the scenarios, it could be useful in the field of movement rehabilitation, for people with development disorders to control their movements and improve their social skills or in the area of forensic psychiatry, i.e. panic attacks, heart disease, epilepsy, or to people who take drugs with large psychological effects. The means of feedback currently in use are mainly subjective questionnaires. By adding cardiac rhythm, sweating and other sensors that track physiological changes to our system we can offer an objective evaluation based on the immediate bodily responses towards the stimuli without the interference of the possible manipulation of the questionnaires by the persons assessed.

Acknowledgements. We would like to thank the executive managers and members of the stuff of the General and Oncology Hospital of Kifissia for agreeing to provide the opportunity to present our work to them and receive their feedback.

At this point, we would like to discuss the expertise of the healthcare facility members we used as evaluators of our system a bit further. The medical staff of the facility we chose consists of experienced, well-trained, highly educated psychiatrists and healthcare attendants, who agreed to test our proposed system and provide their substantial feedback on its efficiency, as well as methods of enhancing it in the future. All of the members have graduated from reputable medical universities and have frequently assisted patients in treating their obsessive/irrational thought and behavioral patterns through exposure therapy sessions. Another important aspect of our preference in this particular psychiatric department is their constant quest for innovative diagnostic and therapeutic techniques. Our system and method are quite original; subsequently, they were highly interested in the new methods in which ET can be enhanced through VR technology. Taking the aforementioned facts into consideration, it is clear that our choice in this particular psychiatric department was everything but coincidental; we strongly believe that the clinic's specialists were the most fitting to evaluate the efficacy of our system in view of their experience and education.

References

1. American psychiatric association: diagnostic and statistical manual of mental disorders, 5th edn. (2013)
2. National Institute of Mental Health: Anxiety Disorder
3. National Institute of Mental Health: Mental Illness
4. Bandelow, B., Michaelis, S.: Epidemiology of anxiety disorders in the 21st century. Dialogues Clin. Neurosci. **17**(3), 327–335 (2015)
5. Kessler, R.C., Berglund, P., Demler, O., Jin, R., Merikangas, K.R., Walters, E.E.: Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. Arch. Gen. Psychiatry **62**, 293–602 (2005)
6. Stinson, F.S.: The epidemiology of DSM-IV specific phobia in the USA: results from the national epidemiologic survey on alcohol and related conditions. Psychol. Med. **37**(March), 1047–1059 (2007)
7. Öst, L.G.: One-session treatment for specific phobias. Behav. Res. Ther. **27**, 1–7 (1989)
8. Scott, J., Beck, A.T.: Cognitive behavioural therapy. In: Essential Psychiatry, 4th edn. (2008)
9. Mayo-Wilson, E., Montgomery, P.: Media-delivered cognitive behavioural therapy and behavioural therapy (self-help) for anxiety disorders in adults. Cochrane Database Syst. Rev. (2013)
10. Treatment - (ADAA) Anxiety and Depression Association of America. https://www.adaa.org/finding-help/treatment
11. Otte, C.: Cognitive behavioral therapy in anxiety disorders: current state of the evidence. Dialogues Clin. Neurosci. **13**(4), 413–421 (2011)
12. Wittchen, H.-U., Mühlig, S., Beesdo, K.: Mental disorders in primary care. Dialogues Clin. Neurosci. **5**(2), 115–128 (2003)

13. Kerns, C.M., Read, K.L., Klugman, J., Kendall, P.C.: Cognitive behavioral therapy for youth with social anxiety: differential short and long-term treatment outcomes. J. Anxiety Disord. **27**(2), 210–215 (2013)
14. Riddle-Walker, L.: Cognitive behaviour therapy for specific phobia of vomiting (Emetophobia): a pilot randomized controlled trial. J. Anxiety Disord. **43**, 14–22 (2016)
15. Krebs, G.: Long-term outcomes of cognitive-behavioral therapy for adolescent body dysmorphic disorder. Behav. Ther. **48**(4), 462–473 (2017)
16. Rozental, A.: A randomized controlled trial of internet-based cognitive behavior therapy for perfectionism including an investigation of outcome predictors. Behav. Res. Ther. **95**, 79–86 (2017)
17. Warwick, H.: Complete recovery from anxiety disorders following cognitive behavior therapy in children and adolescents: a meta-analysis. Clin. Psychol. Rev. **52**, 77–91 (2017)
18. Peñate, W., Fumero, A., Viña, C., Herrero, M., Marrero, R.J., Rivero, F.: A meta-analytic review of neuroimaging studies of specific phobia to small animals. Eur. J. Psychiatry **31**, 1–44 (2017)
19. Twomey, C., O'Reilly, G., Meyer, B.: Effectiveness of an individually-tailored computerised CBT programme (Deprexis) for depression: a meta-analysis. Psychiatry Res. **256**, 371–377 (2017)
20. Ollendick, T.H., Öst, L.G., Ryan, S.M., Capriola, N.N., Reuterskiöld, L.: Harm beliefs and coping expectancies in youth with specific phobias. Behav. Res. Ther. **91**, 51–57 (2017)
21. Shiban, Y., Schelhorn, I., Pauli, P., Mühlberger, A.: Effect of combined multiple contexts and multiple stimuli exposure in spider phobia: a randomized clinical trial in virtual reality. Behav. Res. Ther. **71**, 45–53 (2015)
22. Treanor, M., Craske, M.G.: Exposure therapy. In: Encyclopedia of Mental Health, 2nd edn. (2015)
23. Rothbaum, B.O., Rizzo, A.S., McDaniel, D.D., Zanov, M.V.: Virtual reality exposure therapy. In: Encyclopedia of Mental Health, 2nd edn. (2015)
24. Society of Clinical Psychology: What is Exposure Therapy?. American Psychological Association: Division, vol. 12 (2013)
25. Waters, A.M.: Augmenting one-session treatment of children's specific phobias with attention training to positive stimuli. Behav. Res. Ther. **62**, 107–119 (2014)
26. Rizzo, A., Hartholt, A., Grimani, M., Leeds, A., Liewer, M.: Virtual reality exposure therapy for combat-related posttraumatic stress disorder. In: Computer, Long Beach California (2014)
27. Cardoş, R.A.I., David, O.A., David, D.O.: Virtual reality exposure therapy in flight anxiety: a quantitative meta-analysis. Comput. Hum. Behav. **72**, 371–380 (2017)
28. Bun, P., Gorski, F., Grajewski, D., Wichniarek, R., Zawadzki, P.: Low - cost devices used in virtual reality exposure therapy. Procedia Comput. Sci. **104**, 445–451 (2016)
29. Yiasemidou, M., Siqueira, J., Tomlinson, J., Glassman, D., Stock, S., Gough, M.: Take-home' box trainers are an effective alternative to virtual reality simulators. J. Surg. Res. **213**, 69–74 (2017)
30. Blakey, S.M., Abramowitz, J.S.: The effects of safety behaviors during exposure therapy for anxiety: critical analysis from an inhibitory learning perspective. Clin. Psychol. Rev. **49**, 1–15 (2016)
31. Krijn, M., Emmelkamp, P.M.G., Biemond, R., Schuemie, M.J., Van Der Mast, C.A.P.G.: Treatment of acrophobia in virtual reality: The role of immersion and presence. Behav. Res. Ther. **42**, 229–239 (2004)
32. Emmelkamp, P.M.G., Krijn, M., Hulsbosch, A.M., Vries, S., Schuemie, M.J.: Virtual reality treatment versus exposure in vivo: a comparative evaluation in acrophobia. Behav. Res. Ther. **40**, 509–516 (2002)

33. Carlin, A.S., Hoffman, H.G., Weghorst, S.: Virtual reality and tactile augmentation in the treatment of spider phobia: a case report. Behav. Res. Ther. **35**, 153–158 (1997)
34. Freeman, D.: Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial. Lancet Psychiatry **5**, 625–632 (2018)
35. Price, M., Anderson, P.: The role of presence in virtual reality exposure therapy. J. Anxiety Disord. **21**, 742–751 (2007)
36. Morina, N., Brinkman, W.-P., Hartanto, D., Emmelkamp, P.M.G.: Sense of presence and anxiety during virtual social interactions between a human and virtual humans. PeerJ **2**, e337 (2014)
37. Rudaz, M., Ledermann, T., Margraf, J., Becker, E.S., Craske, M.G.: The moderating role of avoidance behavior on anxiety over time: is there a difference between social anxiety disorder and specific phobia? PLoS ONE **12**, e0180298 (2017)
38. Da Gama, A.E.F., de Menezes Chaves, T., Fallavollita, P., Figueiredo, L.S., Teichrieb, V.: Rehabilitation motion recognition based on the international biomechanical standards. Expert Syst. Appl. **116**, 396–409 (2019)
39. Wang, X., Yan, K.: Immersive human-computer interactive virtual environment using large-scale display system. Future Gener. Comput. Syst. **96**, 649–659 (2017)
40. Chen, J., Qiu, J., Ahn, C.: Construction worker's awkward posture recognition through supervised motion tensor decomposition. Autom. Constr. **77**, 67–81 (2017)
41. Maples-Keller, J.L., Bunnell, B.E., Kim, S.J., Rothbaum, B.O.: The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders. Harvard Rev. Psychiatry **25**, 103 (2017)
42. Morina, N., Ijntema, H., Meyerbröker, K., Emmelkamp, P.M.G.: Can virtual reality exposure therapy gains be generalized to real-life? A meta-analysis of studies applying behavioral assessments. Behav. Res. Ther. **74**, 18–24 (2015)
43. Turner, W.A., Casey, L.M.: Outcomes associated with virtual reality in psychological interventions: where are we now? Clin. Psychol. Rev. **34**, 634–644 (2014)
44. Suh, A., Prophet, J.: The state of immersive technology research: a literature analysis. Comput. Hum. Behav. **86**, 77–90 (2018)
45. Freeman, D.: Virtual reality in the assessment, understanding, and treatment of mental health disorders. Psychol. Med. **47**(14), 2393–2400 (2017)