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Virtual Therapeutics – Requirements to deliver value with virtual reality and biofeedback applications for alcohol addiction therapy

Abstract: The application of virtual reality (VR) as a supportive tool in psychotherapy has gained great popularity in recent years. Especially for addiction therapy, a combination of virtual exposure and learning or training coping skills by using biofeedback has a high potential to improve conventional therapy. To add value, the new therapy system has to meet the needs of patients and practitioners likewise. Added values consistently named by experts included, but were not limited to, new possibilities of creating individual exposition or coping scenarios, enhanced psychoeducation, a shorter duration of treatment, telemedical aspects, the possibility of measuring and predicting craving and finally an improvement in abstinence. Besides literature research, we evaluated existing technical solutions in the field of virtual addiction treatment, surveyed experts and evolved a concept that led to a first prototype. The prototype consists of a wireless VR headset and a wireless multi-sensor system for measuring the physiological reaction to stimuli or the effectiveness of coping strategies by means of biofeedback. For further studies we developed both, a virtual exposure and a coping scenario and tested the hardware and software in a pilot study in order to elaborate factors that could negatively affect the therapy adherence, the effectiveness of exposition (immersion) and possible hurdles in practical use. Cybersickness and the lack of haptic feedback turned out to be the main limiting factors. Concepts for the next iteration of the therapy system will reflect these points for upcoming clinical studies.

In our proof of concept, we demonstrated that virtual therapy can be implemented with a reasonable effort of time and costs.

The combination of software and hardware, that supplements the traditional therapeutic approach, lays the foundation for upcoming clinical use and trials to prove the better outcome of VR enhanced addiction therapy.

Keywords: telemedicine, virtual reality, VR, psychotherapy, virtual therapeutics, addiction, alcohol, addiction disorder, cue exposure therapy, coping strategies, craving, biofeedback, heart rate variability, HRV, autonomic nervous system

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1 A new area of virtual therapy

Since the beginning of the COVID-19 pandemic, German psychotherapists report a 40% increase in requests and more than one third of patients has to wait longer than six months to get a treatment appointment [1]. Especially with the high prevalence of alcohol addiction (1.6 Million in Germany alone) this is a severe problem [2]. A possible solution could be to establish more telemedical therapy concepts, which can be done with a chat, video conference or even a virtual reality or augmented reality system. Addiction therapy usually consists of a variety of therapy modules. Important parts are the promotion of a disease understanding, to develop an awareness for situations, that typically led to the consumption of the substance and to train the patient how to deal with the urge (craving) for the substance. Those common modules are an important part of psychoeducation. By exposing the patient to the stimulus repeatedly, coping mechanisms can be tested and the patient gradually gets desensitized. For some forms of addiction, virtual reality as a therapy-supporting approach has already shown promising results [3].

VR-based exposition scenarios open up the possibility to create highly individual, as well as common, trigger scenarios, which are not dependent on the patient's imagination, pictures, or real-life testing. The measurement and documentation of craving adds another crucial aspect for the patient as well as

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for the therapist - even more, when the activity of the autonomic nervous system directly interacts with the simulation (biofeedback) [4]. To answer whether VR therapy provides a benefit compared to conventional approaches, clinical studies and as a matter of fact, functional prototypes are needed. For this very new approach, there is not much information on which requirements such a combined system needs to meet. Therefore, thorough research was conducted, which will be examined in this work.

2 Research approach

2.1 Literature analysis

To determine whether there is preliminary work in the field of virtual exposure therapy in combination with wearable biofeedback components, we analyzed current (state 09/2020), preferably peer reviewed, literature. For the aspect of behavioral therapy, the search focus was on exposure-based addiction therapy with virtual environments presented through a VR headset. Different methods of measuring physiological reactions were verified in the view of the precision, fault tolerance, ease of use and their suitability for biofeedback applications. Furthermore, ways to measure craving and its extent have been investigated.

2.2 Qualitative expert interviews

To ensure practicality and relevance of a developed scenario as well as to determine the clinical requirements, expert interviews and enquiries were conducted. Several psychiatrists, other addiction related practitioners, therapists, support group instructors and patients were asked about their experiences, preferences and how so-called “serious games” with digital tools like VR could provide added value in the context of exposition therapy. The expert input was a major influence on the design and development of a first VR addiction therapy prototype.

2.3 Market analysis

Considering the requirements and wishes gained from the expert interviews, a search for already available products was conducted. Service providers offering to build individualized systems without having a ready to buy product were excluded just as products that did not meet the European safety standards. The main focus lay on portable systems which

already combine virtual exposure in the context of alcohol addiction, psychoeducation and wireless biofeedback sensors while providing language output and visuals in German. State 09/2020, no system could be found that met all mentioned requirements. Therefore the focus shifted to a proprietary implementation.

2.4 Prototype development

Based on our findings from analyzing relevant literature, market analysis and expert interviews, we developed functional prototypes of VR software and wearable sensory hardware for biofeedback and implemented a path to feed the sensor data back into the simulation.

2.5 Pilot study

To test the system a pilot study with 10 healthy test subjects (age range 21-30 years, $\bar{x}$ =25 years, 4 female, 6 male) was conducted, considering three main aspects: usability (acquired via interview), degree of immersion and disruptive factors (acquired via questionnaire) and utility of the chosen technical components (acquired via benchmarks and comparison with a second headset and different biofeedback sensors).

3 Results and Discussion

3.1 Clinical requirements

Through analyzing the questionnaires and interviews, we identified some key patients' and practitioner's requirements. Our first VR exposition environment should be able to address as many patients as possible. The result of our interviews consistently suggested a shopping scenario because it can be considered as a common critical situation for the majority of alcohol addicted patients. Therefore, a small virtual supermarket has been chosen as the setting for the actual exposition. The interviewees saw great potential in the possibility of reproducible scenarios – exposition and coping scenarios, likewise. Further, more objective therapy progression documentation through captured reactions of the autonomic nervous system, as well as the option for telemedicine and independent home use for learning or training coping strategies was estimated to be one of the most important added values. Shorter therapy, lower relapse rates, objective measurability of craving, prediction of craving (e.g.,

by artificial intelligence) and long-term improvements in terms of therapy accessibility and waiting times have been the expectations of the interviewed therapists.

The practitioners emphasized the need of an easy-to-use software and hardware, that speaks the native language of patients and therapists, whereas costs only play a subordinate role for the clinical use. For future use at home or in support groups, the experts agreed that a portable and wireless system is required. For this reason and because of its low cost, an *Oculus Quest* headset has been chosen, while being aware that these headsets are only suitable for the proof of concept because of data privacy concerns.

To maximize immersion and ensure patient compliance, disruptive factors to their wellbeing have to be minimized. First and foremost, this means reducing cybersickness. Our research revealed that besides the obvious somatic inconveniences like e.g. nausea and dizziness, cybersickness also has influence on the degree of immersion on which the whole concept depends [5]. Therefore, there will be measures like for example locomotion in the virtual world through motion tracking of the users' limbs instead of controller input. This enables the user to move around the virtual environment by walking on the spot or in the best case on a 360-degree treadmill. User tests made clear, that there are great differences in the perception of handling and intuitiveness of the simulation itself, VR-related navigation controls and the sensor equipment. To deal with this problem, the next iteration of the software will take advantage of an interactive tutorial, that introduces the user to all necessary controls and functions, as known from many computer games. The experts expressed the wish to customize scenarios as well as the favorite drink or even brand. To reduce development time, this could be implemented by creating the 3D-models and textures through 3D scans of the real bottles or environments (e.g., patient's home or favorite bar).

3.2 Exposition simulation

Considering the clinical requirements, we developed the VR software using Unreal Engine 4 as well as a wireless chest-worn sensor for measuring the physiological reaction, that can be integrated into the virtual environment. The necessity for the hardware development was caused by the lack of existing products, that matched all requirements.

3.2.1 Virtual environment

Analyzing the literature showed promising results for other addictions, but it also revealed that there is a lack of controlled clinical trial to verify a benefit in comparison with

conventional exposition based behavioral therapy for alcohol addiction [3]. Considering the results and methods of studies with similar intentions [6], [7], we implemented a supermarket scenario suggested by the experts. The aim was to design it as realistic as possible to create a high level of immersion and with that provoke craving during virtual substance exposure. Additionally, a second scenario was implemented as a sunlit meadow in a summery visual and acoustic atmosphere, to be used for learning and practicing coping strategies.

For comparison of the technical performance of the *Oculus Quest*, a second headset, the *HTC Vive Pro*, was tested. The main focus was to determine the technical parameters' influence on the degree of immersion. Differences in field of view, display resolutions and texture quality had little to no impact, according to the participants. Influences through fluctuations in frame rates were moderate. Main disruptors were the lack of physical interaction with the simulated environment and cybersickness.

3.2.2 Wearable biofeedback sensors

The literature analysis revealed that craving for addictive substances like alcohol behaves similar to acute stress by showing significant increases of heart rate and electrodermal activity [8]. This might be used for the automated detection (or even prediction) of craving. HRV and hand temperature measurements are good indicators for relaxation induced by respiratory training and are proven biofeedback methods in addiction therapy [4]. Therefore, the integration of biofeedback could provide an added value especially to coping strategy training in terms of training efficiency and speed, as well as the option to document and visualize the training progress. To utilize this in our first prototype, a multi-sensory HRV measurement unit was developed and clipped to a chest strap for good skin conductance (see Figure 1).

Figure 1: Wireless VR-headset with interactive virtual exposure environment including realistic alcohol bottles and visualization of the bio parameters provided by the chest worn sensor

As the sensor is chest-worn and contains a 3-axis gyroscope and accelerometer, the respiratory rate can easily be obtained as well. All data is then transferred via Bluetooth into the VR environment for a visual biofeedback, as well as for therapeutic monitoring.

4 Conclusion and outlook

For the development of a VR-based system that may enhance the treatment of alcohol related addiction, we initially gathered information from literature, health care professionals involved in the therapy and patients to characterize the needed functionality that went into a first prototype. The developed therapy system's hardware consists of a wireless VR headset and a wireless sensor system, that is capable measuring physiological reactions as a result of the disease-related activation of the autonomous nervous system. On the software side, virtual reality is used to expose the patient in the framework of an exposition therapy and to train the patient to cope with the urge of consumption and to build up resilience and train different coping skills that keep up abstinence. To intensify the effectiveness of this training, biofeedback is used to train the patient, but the sensory data can also be used for an automated adaption of the exposition scenario. At this point, this functionality is not yet implemented in the prototype, but part of the underlying concept. The measurement of the physiological processes allows a documentation of the course of therapy, advanced possibilities in psychoeducation, the advantage of detecting craving and parametrize the therapy progress. As a first example of possible exposition scenarios, a virtual supermarket is used to simulate a situation, most patients are facing in the daily routine and where they cannot avoid the stimulus. The physical reaction is measured with heart rate variability (HRV) and the respiratory rate. The corresponding coping scenario teaches the patient breathing exercises. Breathing depth, frequency and HRV are important parameters, that grade the quality of the self-regulatory effect and intensify the training.

It could be shown that a therapeutic system can be implemented with reasonable efforts. Nevertheless, we spotted some issues related to virtual therapy in a pilot study such as cybersickness and lack of haptic feedback, that affects immersion and the therapeutic effect. Technical measures to avoid those issues are already designed and have to be implemented in the next iteration of the therapy system. There is yet not enough methodically high quality data to prove the benefit of this technology, and even less in combination with biofeedback [3], but there is a high potential

for the combination of biofeedback, virtual cue exposure and coping simulations. Therefore, it is of great interest to refine this technology to meet the clinical requirements and conduct randomized controlled studies.

Authors Statement

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