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Development of a virtual reality simulation for exposure based addiction therapy

Abstract: After the success of virtual reality (VR) applications in supporting exposure-based and psychoeducational cognitive behavioural therapy for various mental illnesses, the technology is also gaining traction in addiction medicine. This paper will describe the concept behind a custom-developed VR simulation for this application with a particular emphasis on alcohol-related addictive disorders. Using Unreal Engine 4, an exposure simulation and a scenario for learning and applying coping strategies were developed for the Oculus Quest. Because of the common association of supermarkets with the procurement of alcohol among addicts, a small shop was implemented as initial scenario. Since the feeling of presence is an important parameter in the quality assessment of a simulation, the degree of immersion was evaluated in initial practical tests after development. In surveys with ten healthy testers, the majority showed a feeling of immersion. Cybersickness and unrealistic collision physics were identified as disruptive factors to the extent of immersion. This work provides the basis for a novel concept for addiction therapy which focusses on a fusion of playful psychoeducation, adjustable exposure, and the internalization of coping strategies with the help of multisensory biofeedback as well as the documentation of the objective physiological measurements for assessment of therapy success. The aim is to best possible address the specific requirements for clinical and home use in terms of self-containment, immersion, and ease of use. To evaluate and exploit the scientific potential of this concept scientific studies and technical improvements to both simulation and hardware are required.

Keywords: virtual reality, VR, virtual therapeutics, addiction, substance use disorder, SUD, alcohol use disorder, AUD, cue exposure therapy, CET, cognitive behavioural therapy, coping strategies, craving, biofeedback, unreal engine, oculus quest

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1 Introduction

Whether for post-traumatic stress disorder, phobias, or disordered eating behaviours, virtual reality (VR) has gained popularity as a supportive tool in the treatment of mental illnesses in recent years due to good therapeutic outcomes [1]. The extensive possibilities of immersion in computer-generated 3D worlds using VR headsets enable practitioners to represent certain scenarios interactively and realistically. The field of addiction medicine has barely tapped into this new medium for therapeutic use. There is still a lack of simple and sophisticated software and accompanying research on patient benefits in comparison or as an adjunct to conventional therapy approaches. Even though scientific data is still scarce, there is reason for tentative optimism.

Provoking addictive pressure through VR-based exposure shows good results and with regard to the efficacy of VR-based addiction therapy, this has also already been demonstrated for some forms of addiction [2]. In addition, there are promising indications which suggest that learning coping strategies in virtual space has a positive effect on craving and abstinence behaviour [2]. From results in the use of VR in the treatment of anxiety disorders, it is known that the anxiety responses (and associated accompanying vegetative symptoms) are particularly strongly dependent on the degree of immersion [3]. Immersion therefore can be seen as a benchmark for the quality of a simulation.

Based on these findings, it can be deduced that there is a correlation between the level of immersion in VR and the successful triggering of craving for addictive disorders. The degree of presence in the virtual world has an impact on the emotional response of anxiety patients [3]. Therefore, it is reasonable that there is a direct correlation between immersion and the probability of a situation to trigger craving in addictive disorders.

At present, this reaction of the patient to a stimulus related to addictive substances is usually recorded with the help of a questionnaire. However, depending on the user's self-observation ability, these questionnaires can provide very

subjective results which may not be easily comparable. A supplementary path could be detection and monitoring of craving via the reaction of the autonomic nervous system during an intervention. The introduction of biofeedback can help to increase the feeling of presence [4] and both heart rate variability and EEG as parameters show good results in the reduction of craving by biofeedback [5], [6]. Further research and development are needed to make such virtual therapy concepts sustainable for patients. Possible approaches include not only the triggering of addictive pressure by artificially generated stimuli, but also psychoeducation, i.e., teaching and training coping strategies with the aid of biofeedback and the documentation of the progress of treatment. Especially in combination with the acquisition and intelligent feedback of physiological parameters into the simulation, new possibilities arise. However, these require a cooperative merger of different fields, such as engineering, computer science and medical research.

Yet this work will initially be limited to the concept behind the software responsible for the simulation as well as the findings from initial functional test runs with healthy volunteers.

2 Materials and methods

2.1 Therapeutic approach

In order to enable people with addictions to have as normal an everyday life as possible, it is of great importance not to associate everyday tasks and places with the addictive substance. Exposure simulations aim to help visiting these situations and places virtually under supervision of a therapist or practitioner. There, patients can practice potentially dangerous situations several times in a protected setting. VR offers a great logistical and immersive advantage compared to standard exposure therapy, which, by default, is based either on visiting the real situation or on imagining a situation in the patient's mind's eye. With VR on the other hand, any environment can be simulated at any time of the day or night without having to leave the practice. In addition, the implementation of such VR simulations is customizable, which means that the patient's individual triggers can be considered and the intensity of the stimulus introduced can be controlled.

The goal is a systematic desensitization with the help of increasing stimuli in combination with relaxation and coping techniques until the triggering cue is well tolerated. The simulation introduced represents a first level of intensity on

which further work can be built with ever increasing stimuli. This first stage should initially only passively expose the user to alcohol. That is, the alcohol is visually present, but the subject is not yet actively prompted, for example by social pressure, to consume the alcohol.

2.2 Exposure and coping scenarios

Since provisioning is common ground with many individual consumption scenarios, there is reason to assume that many of those affected might feel addressed by a simulation broaching this issue. However, the users should be able to decide for themselves whether or not to buy alcohol. Therefore, in this simulation, users find themselves in the situation of going to a small supermarket. They have to work through a shopping list, but the exclusively non-alcoholic products on this list are placed near the alcohol to make the user walk past it and have alcohol in sight while the other products are searched for. If the user does get tempted and wants to buy alcohol, there are gameplay options in the simulation to stop the relapse. If the stimuli introduced become too strong and craving occurs, the user is provided the opportunity to withdraw to another level. The ulterior motive is that the coping level is designed as a calming sanctuary for practicing and the application of individual coping strategies.

2.3 Hardware

For future use in practices and clinics, independence from external tracking systems and additional computing hardware is an advantage. For this reason and because of the low acquisition costs, Facebook's Oculus Quest VR headset was chosen as platform.

2.4 Software

The simulation was implemented entirely in Epic Games Unreal Engine 4. The used version 4.24.3 was preferable to the, at the time of development latest version 4.25, due to the better compatibility with the Android SDK and the purchased additional asset packages. The Android SDK, as well as all other required software packages for the integration of the Oculus Quest, were provided by the NVIDIA CodeWorks 1R7 Android game development tool.

2.5 Functionality tests

A series of tests was conducted with ten subjects to evaluate the level of immersion, usability and subjectively perceived environmental influences. The aim was to determine how immersive the test persons rated the simulation, while at the same time acquiring information about important influencing and disruptive factors on degrees of immersion. Furthermore, the same simulation was run on an HTC Vive Pro Eye VR Headset. Participants were asked whether they experienced any differences regarding the previously queried criteria. The online questionnaire tool SoSciSurvey, which is free of charge for non-commercial, scientific use, served as the evaluation medium.

3 Results and Discussion

In order to ensure the best possible immersion for primarily German patients, the design of the supermarket was oriented as closely as possible to the current look of German supermarkets and discounters. Physics settings such as lighting, dynamic shadowing and gravity for touched objects have also been adjusted to best resemble reality. The used 3D models were rendered as photo-realistic as possible. Photorealism was limited by the computing power of the Oculus Quest, since overloading led to display errors, drops in the frame rate and delayed or falsified light and movement physics display.

The intended features to promote abstinence behaviour were implemented as planned (see Figure 1). When the user picks up an alcohol bottle, a visual message reminds them to reconsider whether they actually want to take the alcohol with them.

Figure 1: Interactive virtual exposure environment with realistic alcohol bottles and visual abstinence aid (Translation of the displayed warning in German: 'Are you sure that you want this?')

The coping simulation was implemented as a sunlit meadow in a summery visual and acoustic atmosphere (see Figure 2).

Figure 2: Low stimulus VR environment for practicing and applying coping techniques

Preparations were also made for integrating sensor data into the simulation. This paves the way to incorporate biofeedback into the simulation environment in the near future.

The user tests carried out produced findings with regard to user-friendliness, the degree of immersion and the performance of the simulation during the various scenarios. While almost all respondents stated that they felt a sense of presence in the simulated supermarket, negative factors influencing this feeling were nonetheless found (see Figure 3).

Figure 3: Perceived sense of presence in the VR environment of ten healthy volunteers. (Answers are translated from German and abbreviated in the figure for visual reasons)

About a quarter of all test subjects suffered from cybersickness during the simulation. Although, in contrast to experiences with flight simulators or travel sickness, the extent of the symptoms observed in the test subjects was limited and was only described as a slight dizziness or a queasy feeling in the epigastric region. None of the test subjects did feel the need to stop the simulation or even vomit. However as determined

through additional interviews, the immersion was negatively affected, especially if the symptoms were greater.

Another factor that had a negative effect on the immersion and was perceived as irritating by almost all participants is the lack of haptic feedback in the event of a collision with the models of the simulation environment.

This might be solved through restrictions of the degrees of freedom and more advanced motion controller hardware.

Neither the technically restricted horizontal binocular field of view nor the display resolution, the latter of which was comparatively low for VR headsets, had a negative impact on immersion. The test subjects were also not bothered by the fact that the 'virtual self' did not have a body, but only had hands with robotic optics. The counter-test with the HTC Vive Pro Eye did not show any apparent advantage in terms of immersion or disruptive factors, according to the test subjects.

4 Conclusion

From studies, experience from related medical fields of application, and our own research results, it is becoming apparent that virtual reality is suitable as a therapeutic tool in addiction treatment, and, furthermore, that it is already technically possible.

However, further efforts must be made to draw on the full potential. For the presented project, this means optimizing the graphical representation of and interaction with the virtual environment (for example, through full-body haptic perception by means of "force feedback"). Beyond that, the challenges lie primarily in expanding the functional scope of the software. A key point here is the consideration of software and hardware measures against motion sickness. This is an important aspect, as motion sickness can significantly disrupt immersion [7].

In terms of combining the system with measurement technology, the focus will be on the simplification of sensor technology and the automatic reaction of the software to addiction-related physiological parameters with the help of artificial intelligence. In our early tests, a fusion of several physiological sensor data is emerging as particularly promising. A combination of time- and location-independent, gamified imparting of the understanding of the disease, suitable coping strategies and targeted and dosable exposure is planned. Also taking into account physiological processes this would revolutionize the therapy of addictive diseases. Despite all the possibilities, this technology will neither replace the practitioner nor existing therapy concepts, but rather aims to complement them in a targeted manner. To be able to establish virtual reality on a broad scale in the clinical or therapeutic

environment, scientific studies are required in addition to technical improvements to prove the patient benefits of VR-supported addiction treatment.

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