Fighting Alcohol Craving Using Virtual Reality: the Role of Social Interaction

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ABSTRACT

Craving is a cause of relapse in patients suffering from a substance use disorder. Cue-exposure therapy builds on eliciting feelings of craving in patients in safe and controlled environments to condition them to control these feelings. Different efficient and resource-friendly methods of eliciting craving exist, (such as written material, still pictures, etc.). However, these methods create knowledge and skill transfer gaps between therapy sessions and real life scenarios. Virtual reality allows more true-to-life experiences, and research demonstrates its capabilities in eliciting craving in patients. Studies have identified different environments that elicits craving, suggesting bars to be one of the most effective ones. Research also suggests the presence of others to be an effective method of eliciting craving in users. However, the effect of social interaction has not yet been explored. Therefore, this paper presents a virtual bar with the purpose to investigate whether social interaction affects alcohol craving in users. The VR intervention is designed with close cooperation with a psychiatrist experienced in working with individuals suffering from alcohol use disorder. In this paper, we present the designed and developed VR intervention and discuss how an experiment can be conducted after the COVID-19 shutdowns.

Index Terms: Human-centered computing—Visualization—Visualization techniques;

1 INTRODUCTION

Alcohol misuse is a major global risk factor for disability and premature loss of life. It has significant economic costs, e.g., regarding law enforcement and healthcare, loss of productivity, and other direct and indirect costs, including harm to others [32]. A recent study discusses how the pandemic of the coronavirus disease 2019 (COVID-19) has created an environment that encourages alcohol consumption [11]. Due to numerous consequences of the virus disease, including social isolation, lack of access to rehab prevention programs and support groups, psychological decompensation and more, they expect an increase in both alcohol relapse and diagnosed patients with alcohol use disorder (AUD) [11]. AUD is defined by behavioral and physical symptoms such as withdrawal, higher tolerance, and craving [3]. AUD may negatively affect e.g., school and job performance, social skills, and childcare. Furthermore, individuals with AUD may be under the influence of alcohol in physically dangerous situations, e.g., while driving, swimming, operating machinery, etc. Finally, these individuals continue to consume alcohol despite their knowledge of its contribution to physical (e.g., blackouts, liver disease), psychological (e.g., depression), social, or interpersonal problems (e.g., violent arguments, child abuse) [3]. To treat patients with AUD, combinations of medication and behavioral assessment is crucial [18]. From a behavioral standpoint, they must correct their cognitive problems by learning to cope with alcohol *craving*, as it often results in the onset of alcohol consumption [3, 8].

This study investigates how virtual reality can help treat patients with AUD. Specifically, we present a virtual bar, including multiple alcohol-craving inducing cues, with the purpose to investigate whether reactions from virtual characters to user actions influence reported levels of craving in participants.

2 RELATED WORK

The Diagnostic and Statistical Manual of Mental Disorders [3] describes *alcohol craving* as an intense desire to consume alcohol that is also more likely to occur in environments and situations, where alcohol has previously been consumed, as well as in conjunction with social factors and the presence of others. Alcohol craving is based on the learning theory component of conditioning [9, 18], where the alcoholic beverage represents an *unconditioned stimulus* and the known effects of drinking it causes an *unconditioned response*. When a previously *neutral stimulus* is repeatedly paired with the *unconditioned stimulus* creating an *unconditioned response*, the neutral stimulus turns into a *cue* that is capable of triggering a *conditioned response* [28]. An illustration of the above is shown in Figure 1.

When addiction and subsequent abuse are predicted to be manifested through reinforcement mechanisms, the conditioned responses can be diminished by exposure to relevant cues through counterconditioning [14]. With prolonged exposure, the *conditioned responses* will gradually lose their reinforcing properties by slowly changing the conditioned responses to the cues. The technique is used in different forms of exposure therapy for treating alcoholism involving repeated, controlled exposures to these cues [7]. Cue exposure therapy (CET) is a behavioristic psychological technique using counterconditioning to treat AUDs [7, 28]. Individuals are continually exposed to relevant alcohol cues, while hindering consumption of alcohol. Repeated exposure to, and separation between unconditioned and conditioned stimuli and cues in counterconditioning will eventually lead to the extinction of the conditioned response of craving alcohol [7]. However, in addition to learning by association and following biological responses, existing socioenvironmental structures and influences also typically affect the effectiveness of the outcome on an individual level.

Typical techniques for cue exposure therapy involve presenting exteroceptive stimuli in a clinical setting - imagining scenarios, reading written material, or by showing still images. Performing therapy in vivo while the patient's habitual behaviour is hindered can be impractical, ineffective, or feel staged due to various reasons [28]. However, current studies on CET effectiveness show limited effects on the primary outcome of limiting alcohol craving. In one study, small additional effects were observed after 6 and 12 months, suggesting that CET may increase in effectiveness over time [7]. Regarding secondary outcomes assessed at 6-month follow-up in the same study, CET had a small additional effect on total drink-

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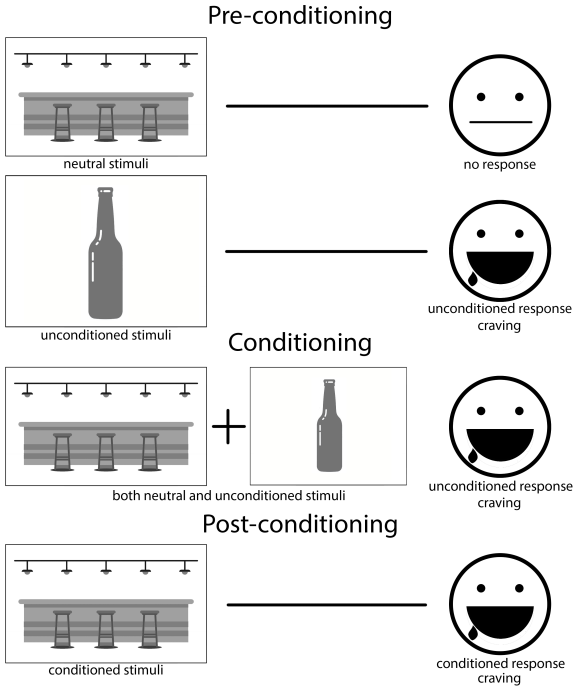

Figure 1: The three elements of pre-, peri-, and post-conditioning resulting in alcohol craving. The images represent stimuli and the faces represent responses.

ing score and a moderate additional effect on latency to relapse. Ex vivo experiences are affected by participant transfer gaps between what is learned in a clinical setting and what is experienced in real life. One reason is considered to be the lack of ecological validity, confirmed by comparison studies where outcomes are different between ex vivo and in vivo conditions. The result is that the nature of ex vivo techniques are hard for patients to apply in a real-world context. Research on exposure therapy has investigated using virtual reality (VR) as an intervention tool to enhance ex vivo experiences. VR is considered able to help close the transfer gap between what is presented in a simulation and what happens in real life [23]. Multisensory immersive VR is considered the next step in digital experiences and interaction [5, 30]. Moreover, VR is also utilized in e.g., therapy, education, design, and training [16]. Possibilities of simulating a high level of sensory fidelity allow individuals to experience feelings of presence, the feeling of 'being there' in a digital world [10]. Presence is a central factor contributing to the effectiveness of a VR experience [35]. Digital sessions happen under controlled circumstances, and can portray scenarios that are not possible or feasible to set up in real life. However, discussions arise on how accurately VR can simulate real world complexity. As such, studies on VR might focus on enhancing aspects of portrayed realism and multisensory input and output. These can determine how much immersion is enough to provide an effective experience, where users achieve feelings of presence [6]. This can be seen in the light of learning-targeted experiences, where simulations can help individuals close transfer gaps between training and practice [16]. Further research is however needed to prove substantial increases in real-world performance. With purely digital experiences come a variable of development time and cost of designing scenarios. A secondary goal is to find a saturation point, balancing between development time, development cost, and effectiveness, especially for learning-targeted experiences [30]. When developing features for a digital experience, a saturation point can be reached if the experiment data shows similar effectiveness outcomes with or without certain features or stimuli. When designing immersive experiences, the perceived degree of realism plays a role when measuring different types of effectiveness of a VR simulation [17]. Experiences taking place in 360-degree prerecorded real-world environments also exist in VR. Such experiences can be easier and faster to create and use in VR. Regarding interaction, however, they are less dynamic, flexible, and adaptable than what can be created through a fully digital environment.

Besides important concepts such as immersion and embodiment, another important part of facilitating presence is to create a dynamic simulation that acts and reacts to user input [5]. Virtual characters can be added to the environment to make it feel alive. Furthermore, to increase believability, engagement, and enjoyment of a mediated experience, characters within the environment should react appropriately to the user's actions [12, 26]. If characters are expected to, but do not respond to user behavior, it can be immersion-breaking [37]. Compared to traditional exposure therapy, such characters can help immerse the user in VR to support experience effectiveness. They can also help in terms of enabling virtual social facilitation of e.g., social pressure or social anxiety, if needed [22].

However, in regard to CET, to our knowledge, no research has been done on whether craving level is affected by virtual characters simulating social interaction.

Cue exposure therapy. Studies using CET for AUD patients were reviewed by Mellentin et. al. [28]. They found evidence of no to small additional effects on drinking intensity and drinking frequency, a small additional effect on total drinking score, and a moderate additional effect on latency to relapse. They found CET could feature an increased effect over time, being effective when combined with craving-specific coping skills. However, CET could prove less effective comparing it to cognitive behavior therapy, when compared to other active control conditions. As an example, one of the studies contrasted using CET to treat alcohol dependence as opposed to a standard cognitive behavioural treatment [27]. They found it equally effective for patients with a moderate severity of alcohol dependence. With the bias and inconsistency of studies in mind, Mellentin et. al. recommend further trials to conclude the effectiveness of CET for treating AUD [28].

Using VR to combine CET and present multiple stimuli. Hone-Blanchet et. al. conducted a meta-review on studies using VR in craving assessment and CET in substance use disorders [18]. They found indications of VR interventions being able to increase craving in participants, but with limited success when used in conjunction with actual CET. Additional studies incorporated elements of dynamic environments in VR [24], two of them also including social pressure [8, 25]. They found social pressure to be very effective in eliciting alcohol craving in participants [8, 25].

Measuring craving. Using scales to measure the subjective state of craving have been used in both behavioral and medication treatment studies, and results indicate that craving is experienced both during drug use, drug withdrawal, and during periods of abstinence [29]. The measure is tricky, because craving episodes can vary in both intensity, latency, frequency, and salience [18].

Different scales exist, from single-item visual analog scales to multiple-item dedicated measuring scales for e.g., urge, craving or obsessive-compulsive drinking. For assessing craving in VR, the 2007 VR study uses questionnaires and scales, namely, the Penn Alcohol Craving Scale (PACS), the Alcohol Urge Questionnaire (AUQ), and the Obsessive-Compulsive Drinking Scale (OCDS) [24]. The PACS is a five-item scale focusing on the urge that the participant felt to drink during the previous week, using a 7-point scale. The AUQ consists of eight items asking about the present mental

state, such as dependence on and preoccupation with alcohol, using a 7-point scale. The OCDS consists of 14 items that quantify thoughts about alcohol and drinking behavior, using a 5-point scale. These tried-and-tested questionnaires can be effective in measuring craving and similar behaviors, but are not part of the intervention in VR itself. An approach–avoidance task was used in a study where participants should move away from alcohol-related situations and approach nonalcohol-related situations [20]; an approach that does not utilize external non-environmental measuring, which removes the immersion of being in VR. The quantitative measurement is done while participants act and react to cues in VR, maintaining the feelings of presence in participants.

A single-item visual analog scale (VAS) has also been used to measure craving at a certain point in time of an experiment [18]. The single-item VAS shows a vertical mark along a line that connects two anchor statements, e.g., experiencing craving and no craving [13]. The distance between the "no-craving" end of the line and the patient's mark serves as the index of craving. The single-item VAS presents itself as a straightforward and time-efficient approach to assessing a patient's level of subjective craving. However, there is no consistency in studies between the question associated with the item, how many points should be available to choose from, and when the question is asked. Moreover, limitations apply when more information about the multiple elements that can define the craving experience is needed, and the internal consistency of the instrument cannot be determined when there is only one item [13]. Hence, single-item VAS measurements on craving traditionally have been done as a secondary measure. The idea of craving as a measurement and a representation as a marker of rehabilitation and treatment success has been disputed, with questionnaires as above having served as the main measurements of craving [18]. However, VR might enhance the fidelity of social or environmental cues and immersion that is presented to a patient. As such, using craving as a measurement just by presenting a single-item VAS might be more valid, as patients are more immersed in the experience than traditional ex vivo cue exposure techniques.

Social Facilitation through Perceived Social Realism. Social facilitation happens when behaviour is influenced by other individuals present without necessarily interacting with the user. Several studies have assessed whether it is possible to simulate this effect in a VE [4, 19, 31]. One explored the relationship between subjectively assessed social characteristics of VR such as co-presence, presence, realism, and their effect on social facilitation [34]. Findings suggest that a high degree of perceived social realism influence social facilitation. Another study investigated realistic versus stylized (simple and sketched style) renderings of virtual characters in VEs featuring three different moods - friendly, unfriendly, and sad [38]. The difference in stylization did not change the level of comfort or presence for participants, but seeing realistic characters did elicit stronger responses. Adding basic social interactions in VEs, such as verbal salutations, gaze, and other gestures by characters towards the user, further contributes to this effect [21]. Findings in both studies underline how social facilitation through social realism can enhance feelings of presence in the VE.

In all, using head-mounted display-based VR can enable interventions to immersse users in an environment with contexts and cues eliciting alcohol craving in participants. Craving can be measured using traditional scales or questionnaires, but also quantitatively while participants are in VR, reducing the risk of breaking immersion. With improved technology, new studies can compare results to previous studies on the effectiveness of using VR in CET. However, with the broad and dynamic range of possibilities of a constructed virtual implementation, it is necessary to determine which elements of the environment provide the most substantial increases in immersion and engagement with respect to effectiveness when developing the application.

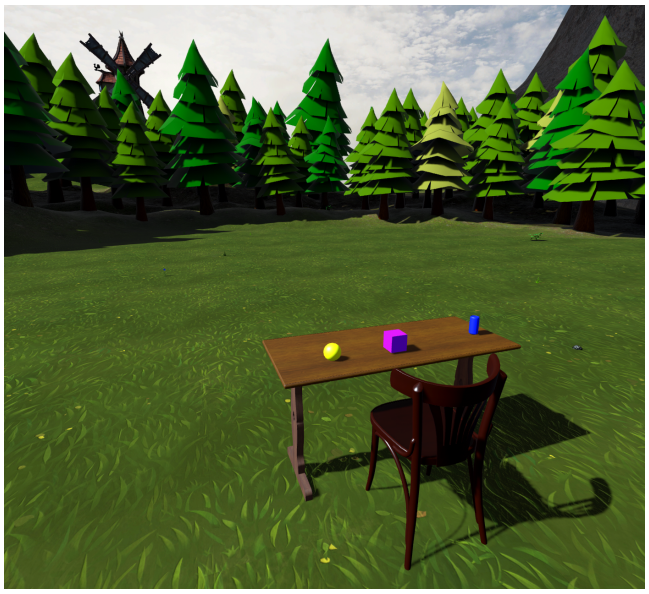

Figure 2: Overview of the neutral setting

3 Design and Implementation

3.1 VR Experience Design

Throughout the design process, multiple meetings were conducted with a medical doctor from Rigshospitalet with expertise in psychiatry. Meetings included brainstorming and receiving feedback on current design ideas and general direction of the project.

This section will cover the design of the VR experience which contains two settings - the bar and a neutral setting.

3.1.1 The Neutral Setting

The neutral setting is created to establish a baseline in craving level before, between, and after conditions in the experiment, thus no alcohol related cues should be present in it (see Section **??** - Experiment Design). It should also allow participants to familiarize themselves with VR in general, including the implemented VR interaction and the body ownership illusion. In the scene, the user is sat by a table with simple interactive objects placed on it. The setting contains natural elements such as trees, flowers, and a mountain. See Figure 2. To create a realistic atmosphere and 'feel' in the bar, 14 animated virtual characters populate the bar as patrons. Audio-wise, a spatialized soundscape of outside traffic, music from speakers, as well as patrons conversing with each other. To make the environment more dynamic, the user can interact with certain objects and patrons.

3.1.2 The Bar

The bar is designed to look and feel natural and realistic to approach a true-to-life experience. To achieve a realistic look, the bar is modelled after the real bar *Tagensborg* in *Copenhagen*.

Interactions The interactive objects in the environment comprise bottles, ashtrays, drink menu folders, and beer glasses. These support being grabbed and put down with sound effects, as well as showing the spilling of liquid from bottles. Objects are affected by gravity and surfaces register collisions with other objects in the environment as well as the user's virtual hand.

Five of the virtual patrons can react to user actions. When a reaction is triggered, animations and an associated audio clips are played. An overview of the reaction events and how these are triggered by the user is shown in Figure 4.

The final design of the bar is shown in Figure 3 and Figure 5.

Figure 3: Overview of the back of the virtual bar.

The Plot Within the bar, the user is seated by the angled table as shown in Figure 6.

The design of the plot focuses on promoting alcohol craving-inducing cues. The developed manuscript is shown in Appendix A. It contains the following key events:

- The user sits at a table. In front of them is a drink menu.
- A friend of the user enters the bar through the main door, approaches at the user while waving and shouting ”hi”, and explains that he is sorry he is late.
- The friend says that he will go to the bar counter and grab something to drink for the user and himself (the drink type is predetermined based on a screening questionnaire.
- After some time, the friend returns to the table with the drinks and sits down in front of the user. The friend talks a bit about how nice it is to finally relax after a stressful period, and then sits and looks around in the bar for some time without talking.
- Later, in the back end of the bar behind the user, four guys at a table yell and celebrate with a toast. The friend then grabs his beer and initiates a toast with the user and starts drinking.

During the plot, the user has the possibility of triggering social reactions from patrons at the bar, during three stages of the plot:

- Before the friend enters the bar
- When the friend is waiting for drinks at the bar counter
- When the friend sits at the table looking around without talking. Here, the friend also reacts to user behavior.

3.1.3 Button Panel

Finally, a button panel is designed to let users enter their craving level on a scale from 0 to 100. The scale’s current value is incremented and decremented by pressing the arrow pointing right and the arrow pointing left, respectively. The ’OK’ button is pressed to enter the current value. See Figure 7.

Trigger	Reaction Event
Looking at the TV on the wall	Patron watching soccer on the TV looks at user and asks about the game
Looking at the fan in the ceiling	Patron watching soccer on the TV looks at user and comments on the fan
Looking at the patrons at the big round table	Patron 1 notices user and nods
Looking at the patrons at the big round table	Patron 2 notices user and asks if they need anything
Looking at the patrons at the big round table	Patron 3 notices user, but looks away again
Looking at the slot machines across the room	Friend comments on the slot machines
Looking at any of the paintings on the wall	Friend comments on the paintings on the wall
Tilting the beer more than 45 degrees or knocking it over entirely	Friend is surprised and tells the user that he might have had enough
Grabbing the drink menu	Friend asks about the drink menu

Figure 4: Table of possible reactions that the user can trigger. The left column shows user actions that trigger the associated reaction in right column.

Figure 5: Overview of the front of the virtual bar.

Figure 6: Inside the bar seen from the user's point of view.

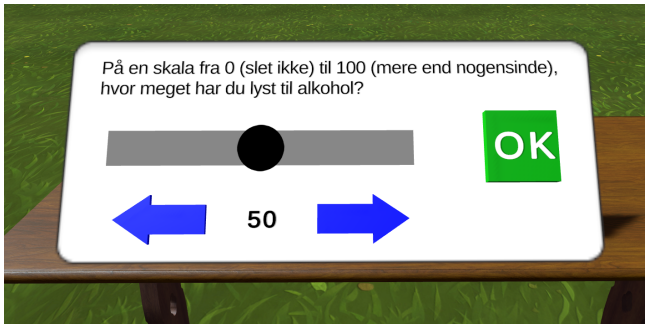

Figure 7: The button panel presented to the user. The buttons are physical and provide visual and haptic feedback. The interface says: from a scale from 0 (absolutely not) to 100 (more than ever) how much do you wish to have alcohol?

3.2 Implementation

The application was developed in *Unity (v. 2020.12)* [36] with supplementary plugins: the *OpenVR (v. 1.11)* SDK for VR implementation [33], the Google Resonance Audio SDK for Unity (v. 1.2.1) for spatial audio implementation [15], and *LipSync Pro (v. 1.531)* for generating mouth movement [2]. On-location photographs, measurements, and audio recordings of the bar were used as references for implementation. The view of the street from inside the bar was created using a 360-degree stitched photo from Google Street View wrapped around the building. A flowchart illustrating the entire implementation pipeline of three aspects of the VE categorized as *virtual characters*, *geometry*, and *audio*, as well as the tools and plugins used, is shown in Figure 8 below:

The characters were animated using a motion capture system comprising a HTC Vive Pro head-mounted display for head tracking, two Valve Index Controllers for hand and finger tracking, and three additional HTC Vive Trackers for tracking the hip and feet. These were tracked in a 5x5 meter space by 4 Valve Index Base Stations. The software *Glycon3D* was used for capturing and recording motion capture data [1]. Lip synchronization was implemented using the *LipSync Pro* plugin for Unity. To prepare a character for lip synchronization, blendshapes were first made for every viseme. The plugin was then used for automatically detecting phonemes from dialog audio recordings. After detecting phonemes, LipSync Pro was run to synchronize visemes and phonemes in a new file. To finally animate lip movement synchronized with recorded dialog,

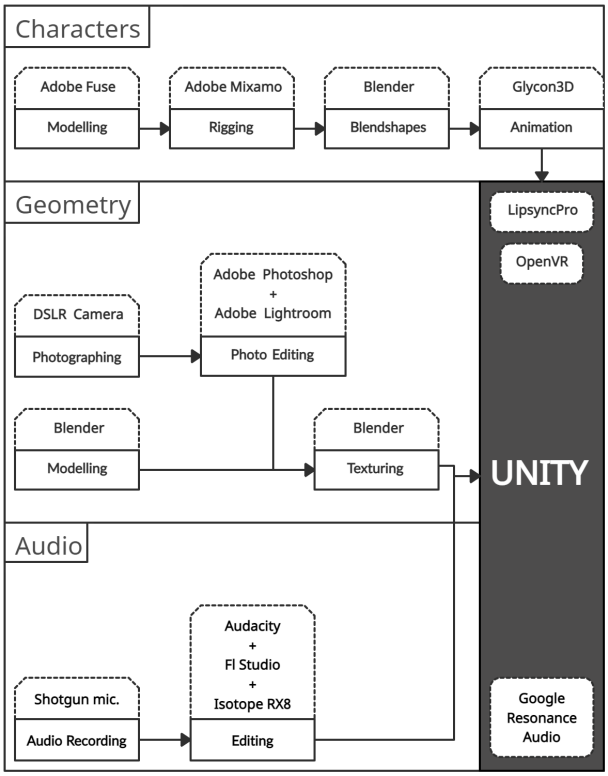

Figure 8: Flow chart illustrating the workflow in implementing the three aspects of the VE (characters, geometry, and audio) into Unity. Each aspect is split into its own section with arrows indicating the direction of the workflow. The dashed lined boxes indicate tools, and the solid boxes below indicate what the tools have been used for. Plugins used in Unity is shown with a dashed lined box inside the 'Unity' section.

this file and the audio file is played simultaneously.

The Google Resonance SDK for Unity was used to implement head-related transfer functions that enables audio to be spatialized, introducing differences in delay and volume received by each ear. Occlusion is enabled to let audio sources sound obstructed by an object on its way to the user. Reverb probes with the characteristics of the wall materials of the settings were baked to match sound qualities to the environment. The implementation tweaked parameters such as sound occlusion, doppler effect, room reverb and reflectivity, as well as directivity patterns for both sources and listeners.

Every reaction from characters consists of an animation and an audio file. The system for controlling reactions was implemented as a script that triggers a reaction when the criteria for that reaction is met. Currently, there are three different criteria: *looking at a specific object in the environment*, *touching a specific object* or *knocking over an object*. To determine where the user is looking, a raycast is used to calculate a straight forward direction from the camera to any objects placed on a predefined physics layer.

4 Discussion

The discussion will touch upon some of the design choices made throughout the project, both in regards to the VR experience as well as the future experiment after the COVID-19 crises. Design choices will be argued for, and alternatives will be discussed. Enabling the user to move using any locomotion technique during the experience would have allowed for more social interactions with the virtual characters, by e.g., moving towards characters sitting further away

and making them react when the user approaches them. The primary reason for not implementing locomotion was to have a more controlled environment, where all users would experience the same plot and not miss any crucial part.

A within-subject design approach is preferred over a between-subjects design for the future experiment. Participants might have a different subjective perception of what a specific craving level is - that is, two participants experiencing the same level of craving might submit remarkably different scores when assessed. Additionally, the bar setting might not be appealing to everyone, and using a between-subjects design could skew results significantly, especially if the sample size for the study is small. A negative aspect of having a within-subjects design is that it might introduce participant bias. However, to mitigate this, the desired outcome of the study is not mentioned to the participants during briefing. Also, the order of conditions a participant experiences is randomized.

Typical implementations of indirect interaction initiated by users in virtual environments are either done by eye gaze or by using controllers. They produce consistent feedback and are triggered easily, as they are natural and intuitive for the user to initiate. Adding microphone input and natural language processing would add an auditory dimension of interaction by having the system listen to the voice input of the user and respond if it hears a predefined word or sentence. I.e., responses to words typically used when talking about beverages, music, other objects, or the virtual characters found in the bar.

Multiple designs were discussed for how to measure participant levels of craving in VR. Here, a button panel was designed with focus on simplicity in both design and interaction. An advantage of the design is how the physical buttons provide both visual, auditory, and haptic feedback when pushed. A concern would be how the button panel appears in front of the user, due to its non-contextual nature in the setting. While it could potentially reduce the feeling of presence for the user, it was deemed a necessity to be able to measure craving throughout the experience in VR. Alternative methods were discussed such as having the friend in the plot ask the user about his current levels of craving, or by having the user report it using voice recognition. Ultimately, these methods were unfit for the overall plot of the experience.

Continuing the study, it would be interesting to investigate whether a saturation point might occur in terms of the fidelity of social interaction and experienced craving level. This study serves as a preliminary study to see if any difference in craving levels can be measured. Thus, only two conditions were implemented, as having more conditions would require significantly longer implementation time, introduce more variables, and would not necessarily provide more interesting results.

5 Conclusion

Previous studies reveal the possibility for VR to be used as a tool for cue exposure therapy. VR can provide enhanced immersion in dynamic and interactive environments when compared to traditional methods, and evidence of VR being capable of eliciting craving in users exist. The effect of different cues have been explored, and social pressure has been identified as an effective cue. The possibility of social interaction in any mediated experience results in higher levels of immersion and general believability in the virtual environment, contributing to a more engaging experience. However, whether social interaction affects alcohol craving has not yet been explored. Thus, this study investigates how social interaction in a virtual bar influences alcohol craving in users. To do so, the design of the experiment was developed in cooperation with a medical doctor with expertise in psychiatry.

Regarding the outcome of the experiment, researchers of the study expect the level of craving and the level of presence to be higher in the condition, where characters react to the user's actions. This is expected, as previous research suggests social facilitation to influence the users, and character awareness to increase character believability, engagement, and enjoyment. Furthermore, studies see a correlation between level of presence and effectiveness of the experience. We expect that feelings of cybersickness to reduce the craving level and level of presence. This is due to it being potentially immersion-breaking and distracting for users experiencing cybersickness.

Finally, a challenge lies in using technology for therapy due to the risk of accidentally causing a negative influence on patient alcohol rehabilitation. More collaboration with experts from technical and medical fields is needed to understand and overcome these issues. With a greater understanding of how VR technology can be implemented as a tool in therapeutical settings, we may one day be able to create more ecologically valid cue exposure treatment environments.

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