# Development of an alcohol refusal training in Immersive Virtual Reality for patients with Mild to Borderline Intellectual Disability and Alcohol Use Disorder: Co-creation and evaluation with experts in addiction care.

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## *Abstract*

**Background:** People with a Mild to Borderline Intellectual Disability (MBID, IQ = 50-85) are particularly affected by Alcohol Use Disorders (AUDs). Given their susceptibility to peer pressure, patients with MBID and AUD should learn refusal skills in a tailored manner to avoid relapse. For this, Immersive Virtual Reality (IVR) appears promising to train managing peer pressure in a playful manner, given that conventional role-plays in the clinical setting lack realistic situations and standardizable actors. However, such complex social interactions have not yet been explored in IVR for MBID/AUD.

**Objective:** We aimed to develop an IVR peer pressure simulation for AUD therapies in patients with MBID and AUD. For this, we involved experts from an addiction clinic for our initial Persuasive System Design (PSD) and exploration of usability, immersion procedures, and therapeutic goals for IVR therapy.

**Methods:** We conducted a comprehensive co-creation method with five experts (i.e. psychologist, nurse specialist, psychomotor therapist, psychiatrist) from a Dutch addiction clinic for people with MBID and substance use disorder. Three focus groups were held to design the IVR environment, persuasive virtual agent, and dialogue. Afterwards, we developed and tested our IVR prototype with the same experts to improve the application/procedures and discuss promising IVR therapy approaches.

**Results:** Our experts described visiting a friend at home with multiple friends to be the most relevant social situation for relapse. Together with the experts, we designed an IVR peer pressure simulation, during which patients can select coping responses of various riskiness levels to train proper refusal scripts. Our expert-based evaluation showed the need for natural speech with paralinguistic features and group dynamics (e.g. two against one) to improve the agent's persuasive power. Further, facilitators (e.g. embodied interactions) and barriers (e.g. text-based procedures) for usability were reported. For clinical applications, IVE difficulty, content, and therapeutic goals should be tailorable to the patient's needs. Lastly, experts preferred therapist-delivered interventions over stand-alone approaches to avoid a perilous trial and error.

**Conclusions:** Our work establishes a first PSD for IVR peer pressure simulations in patients with MBID and AUD. With this, scholars can create comparable IVR simulations using an analogous co-creation approach, replicate findings, and identify active PSD elements. To boost the persuasive power of virtual humans, delivering subtle emotional information (e.g. paralinguistics) and group dynamics are promising. However, previous rapport building may be needed to ensure that agents are experienced as cognitively capable entities with certain (persuasive) power. Future works should validate our PSD with patients and explore therapeutic goals, including treatment protocols, using interdisciplinary teams.

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**Keywords:** Virtual Reality; Conversational Agent; Embodied Agent; Persuasion; Addiction; Alcohol; Intellectual Disability

# Introduction

## Background

People with a Mild to Borderline Intellectual Disability (MBID) are exceptionally affected by the burden of Alcohol Use Disorders (AUDs). MBID combines the groups mild intellectual disability (IQ = 50-69) and borderline intellectual functioning (IQ = 70-85). About fifteen percent of the population have such lower intellectual and adaptive abilities (e.g. related to problem solving, abstract thinking, and planning) [1]. Over past decades, research in this group revealed that people with MBID are prone to develop AUDs [2, 3]. Considering the prevalence of MBID, this constitutes a serious public health problem that should be addressed in prevention/intervention programs [2]. For instance by using digital health [4], as most available treatments are not tailored to the diverse needs and limitations [5], resulting in a lower treatment efficacy for this group [2].

Different factors of intra and interpersonal nature were identified to cause relapse after alcohol detoxification [6], such as limited self-efficacy, coping, and social skills [7]. However, people with MBID and AUD are specifically vulnerable to relapse in social contexts, given their susceptibility to peer pressure and lacking adaptive skills to refuse drinking [8-12]. Peer pressure can be divided into two types: The first, direct peer pressure, involves (verbal) contact with another person. The second, indirect pressure, however, implies observing the person or group associated with the substance of interest. The psychological working mechanism can be illustrated using the theory of planned behavior [13]. Accordingly, the patient's attitudes to remain abstinent are in conflict with the subjective norm to use alcohol, causing dissonance (i.e. psychological stress because of contradictory messages). Hence, conformity towards the subjective norm can emerge to eliminate the internal (i.e. attitude) instead of external (i.e. violating norm) conflict, as people with MBID and AUD lack self-efficacy (i.e. belief in one's power) to refuse alcohol.

Therefore, training refusal skills to resist this pressure and build positive social networks constitutes a regular practice in drug rehabilitation [7], for instance through role-play, that allows training and rehearsing risk situations to boost the patient's self-efficacy [6]. Still, these re-enactments or fictional situations in the clinical setting lack ecologically valid environments to account for the indirect peer pressure. Moreover, trained professionals and other actors are required, which might complicate rehearsal. Yet, these practical trainings appear essential for treating people with MBID and AUD, as unadapted talk therapies are too complex [14]. Here, digital health interventions could help, for instance by practicing these refusal skills in Immersive Virtual Reality (IVR). In computer-generated risk contexts, persuasive virtual humans (i.e. virtual agents) could be implemented to simulate peer pressure in and authentic and standardizable manner [15].

Persuasive technologies can be defined as (interactive) technologies designed to change attitudes and/or behaviors, acting as tool (to increase capability), as media (to provide experience), and/or as social actor (to create relationship) – the so-called *functional triad* [16]. This paradigm forms one of the underlying key constructs of the Persuasive System Design (PSD) model [17, 18]. In this, Oinas-Kukkonen and Harjumaa (2009) described a theoretical analysis of the persuasive intent, event and strategy, as well as subsequent implementation of design features to create Behavior Change Support Systems (BCSS). Looking into existing research, persuasive virtual humans were explored for positive behavior change in (mental) health care [19-21], with promising results. Contrarily, to learn refusal skills our IVR should contain virtual agents to simulate harmful interpersonal influences (toward alcohol consumption). Therefore, the intended persuasiveness may be described twofold, as (1) simulation of interpersonal influences toward alcohol use, and (2) behavior change support to develop refusal skills [18, 22].

To our knowledge, design guidelines for such persuasive system have not yet been explored in IVR for AUDs [4]. Hence, we aim to explore guidelines for IVR peer pressure simulations for therapeutic purposes in people with MBID and AUD. For this, we followed the PSD model to investigate active persuasive design elements and avoid blackboxing [23]. The following research questions should be answered by a co-creation with experts in addiction care for our group:

(1) How to design the Immersive Virtual Environment (IVE)?
(2) How to design the persuasive virtual agent?
    (2.1) How to design the virtual agent's appearance?
    (2.2) How to design the persuasive dialogue?
(3) How do the experts experience the IVR with regard to clinical usage?

## Related work

In the following sections, we report on prior work regarding (1) IVR for AUDs, (2) influential Embodied Conversational Agents (ECAs), and (3) feedback to enhance the patient's self-efficacy.

### *Immersive Virtual Reality – A promising medium to simulate peer pressure*

IVR applications enable us to develop simulations of risk situations causing relapse in people with MBID and AUD [4, 24], with prospect for accessible and engaging interventions that allow for a *doing instead of talking* approach [25]. The affected patients can feel present in safe and controllable Immersive Virtual Environments (IVEs) to experience cause and effect of their behavior [26]. Habits can be triggered to sensitize for peer pressure and related cravings, allowing to practice refusal skills realistically. Previous work on IVR for AUDs mainly studied cue reactivity, a conditioned response when exposed to addiction-related stimuli (i.e. subjective craving, physiological responses). For this, primarily complex cue reactivity IVEs with proximal (e.g. beer can), distal (e.g. cocktail bar), and social (e.g. beer offering agent) cues were used [24]. Here, treatment protocols based on Exposure Therapy (VRET), aiming to systematically remove the conditioned responses, showed deflating effects [4]. Instead, implementing (embodied) learning approaches has been suggested to foster long-term abstinence through behavior change [4]. Considering the impact of peer pressure on abstinence and vulnerability of people with MBID, simulating common peer pressure situations in IVR forms a promising treatment approach that matches the cognitive needs of our group [15]. However, until now, virtual humans in IVR for AUDs lack sophisticated conversational abilities with scientifically grounded features to simulate complex persuasive interactions. Yet, first effects of social cues on cue reactivity were identified [27, 28].

## *Persuasive Embodied Conversational Agents – Social actors to elicit normative pressure*

Similar to human-human interactions [29], ECAs were studied to influence human beings using persuasive strategies [30]. ECAs, also known as intelligent virtual agents, are digital interfaces with a body (part), capable to converse with humans by using modalities such as speech, gestures, and facial expressions. In their work, Reeves and Nass (1996) found that humans react socially similar to social cues delivered via computer systems when compared to human-human conversations [31]. This established the *computers are social actors* paradigm [32, 33]. Since then, conversational abilities of digital systems have become more sophisticated, enabling us to create virtual humans that utilize complex social influences, such as persuasion. As described earlier, different models exist that guide the implementation of persuasive design features (see [16, 18, 23, 29]). Till now, however, no research investigated the persuasive capabilities for IVR peer pressure simulations, nor explored persuasive ECAs for people with MBID [12]. We merely found a single work that used an ECA via a 2D screen for vocational training in people with multiple neurodevelopmental disorders, indicating that social skills and self-efficacy can be enhanced by training with virtual agents [34, 35]. Further, ECAs for AUD screening/counseling in the general population were developed [36, 37].

Various scholars, however, studied social influences via ECAs, for positive change in education and (mental) health [38-44]. In this context, using virtual humans as source of persuasive messages has been shown to affect the effectiveness of the implemented persuasion strategy [30, 45], for example in framing messages [46]. The investigated ECAs predominantly used informational social influences (the need to be right) [47-52], though mostly normative influences (the need to be liked) with relational behavior (e.g. building rapport [38-44], ice-breaking [49-51], mimicry [53, 54]) appear crucial for simulations of peer pressure. Moreover, persuading toward alcohol use will mostly rely on appeals to emotion, thus logical fallacies, and normative influences, such as expectations by peers. Yet, Lucas et al. (2019) reported deflating results when comparing both influences, indicating that informative influences may be powerfuller than normative ones [30]. Further, previous work revealed restrictions in using social influence techniques (e.g. anger), as ECAs are considered as low in power [30, 52]. Nonetheless, as AUD refers to a preconditioned habit, we hypothesize that the persuasive power will be sufficient for using banter/provoking social exclusion [55]. For this, ideally a peer leader should emphasize the violation of group norms to enforce conformity [52].

## *Training refusal skills using feedback – Building a tool to boost the patient's self-efficacy*

To train appropriate social scripts that could strengthen self-efficacy in resisting peer pressure (i.e. reducing the likelihood of conformity), the envisioned IVR system should provide feedback with respect to the user's capabilities. Social (or behavioral) scripts can be described as a series of behaviors, actions, and consequences that are anticipated in specific situations or contexts (e.g. interpersonal communication), derived from social roles, norms, and past experiences, to reduce the cognitive workload [56]. When using IVR simulations of peer pressure, people with MBID and AUD can practice social (refusal) scripts repeatedly through experience of cause and effect without fearing consequences. Similar work has been published for people with autism spectrum disorder, though no explicit persuasive features used, indicating that IVR is an auspicious medium for social skills training [35, 57]. Here, to further stimulate learning, behavior change techniques can be implemented, for instance as formative feedback to improve self-monitoring [58], eventually functioning as corrective during trainings [59]. The use of such feedback constitutes a regular practice in IVR learning tasks for people with MBID [60], for instance by using visual, auditory, or tactile cues in the IVR [61-65]. Kim et al. (2021) explored the attention toward multisensory cues (i.e. visual, auditory, and tactile) in people with intellectual disability using IVR [66], indicating that exogenous cues are more effective than endogenous ones, though visual cues were functional in both, endogenous and exogenous conditions. Hence, our IVR will provide visual feedback to show riskiness during ECA interactions to support patients with MBID in forming proper social scripts for alcohol refusal.

# Methods

## Co-creation approach

We followed the PSD model to specify our prototype requirements and guide the implementation of related persuasive design features [18]. Building on our theoretical analysis of the persuasive intent, event, and strategy (see related work), we conducted three focus groups with experts to further grasp and co-create the persuasion context in IVR (Figure 1), by focusing on the (1) IVE, (2) ECA appearance, and (3) persuasive dialogue. From our theoretically and empirically derived requirements, we built the IVR prototype and evaluated it with the same experts to discuss the user experience for patient usage and intention to use the system in clinical practice.

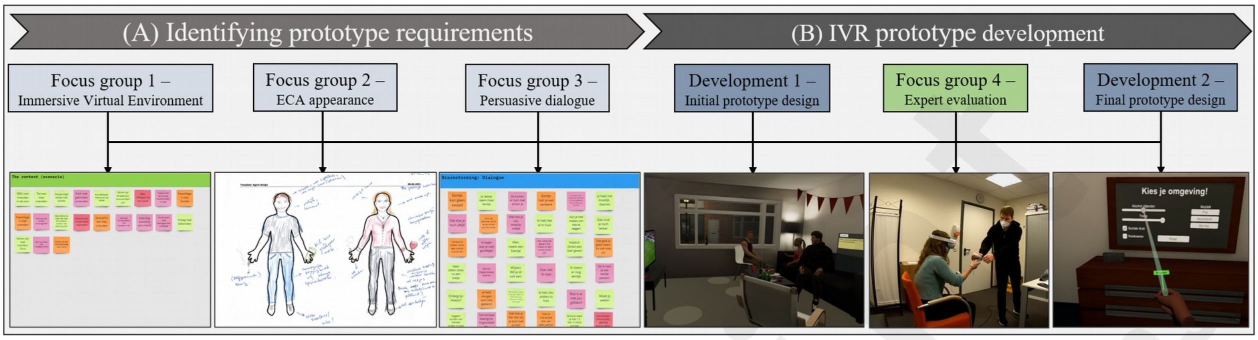


**Figure 1.** The co-creation approach: (A) Identifying the initial prototype requirements throughout three focus groups using the Miro platform and (B) the IVR prototype development, along with an expert try-out and focus group to refine our initial design.

## IVR interaction framework

The identified design requirements from our three co-creation sessions were implemented into our existing IVR interaction framework for people with MBID (Figure 2). It was developed throughout multiple studies with various degrees of embodiment (i.e. controller, full body, virtual hands) and locomotion techniques (e.g. teleport, joystick) [67]. The final design comprises a virtual hand embodiment and teleport locomotion (raycasting with projectile curve, Figure 2B) to pre-defined anchors with an around 2x2 meter room-scale area for natural locomotion. Moreover, we implemented raycasting for user interface (UI, Figure 2D) interactions and sphere-casting (via virtual hands) to pick-up objects from the ground (Figure 2C). Instructional scaffolding was used to aid button recognition and users are able to customize their skin tone during an initial tutorial. Lastly, we used a Visual Analogue Scale (VAS, Figure 2D) that can be activated within the user's screen space, integrated with a 45-degree snap around the Y-axis for measuring during treatment or research [68]. The IVR interaction framework was built in Unity3D using the XR interaction toolkit (preview, v.1.0).

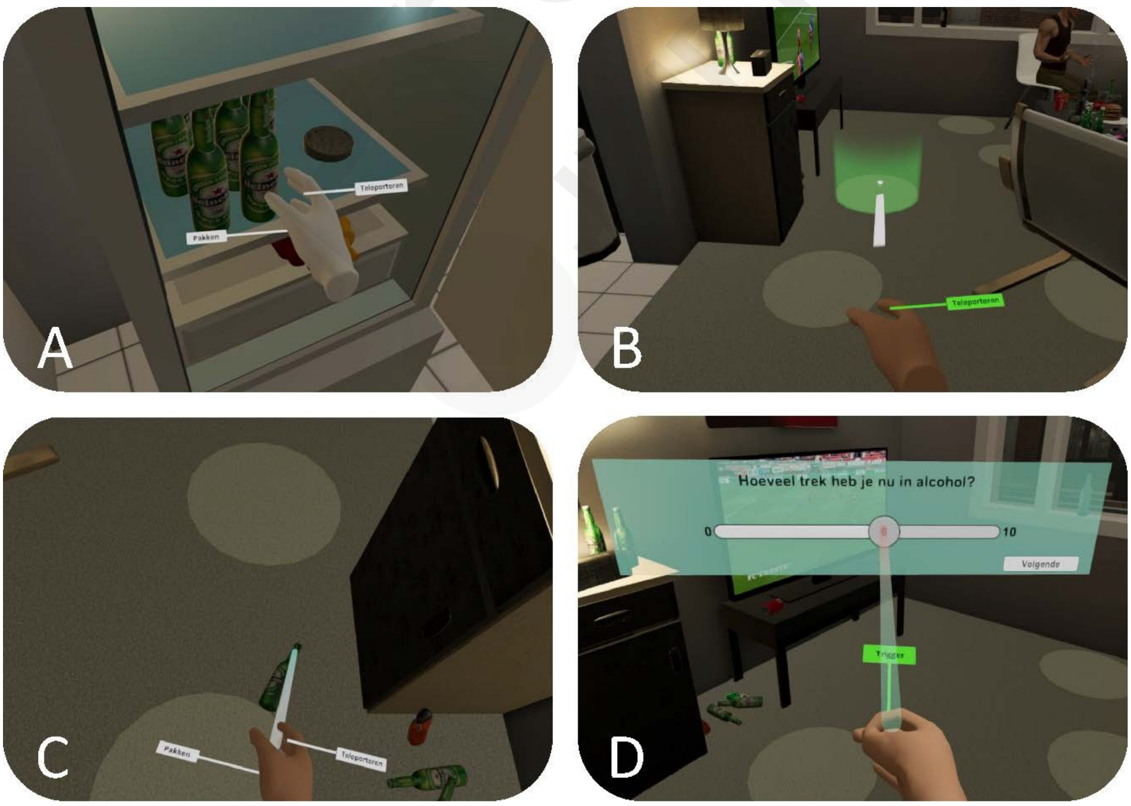

**Figure 2.** The IVR interaction framework: (A) Virtual hands with instructional scaffolding aids (displaying in Dutch: 'grabbing' and 'teleporting'), (B) teleport locomotion to anchors, (C) sphere-cast interaction to pick-up objects, and (D) Visual Analogue Scale (VAS, displaying '*How much do you crave for alcohol now ?*') interaction using the 'trigger' button.

# Participants

We included therapists (psychologist, psychiatrist), nurse specialists, and psychomotor therapists from a Dutch addiction clinic that are actively involved in the treatment of individuals with MBID and AUD for co-creation purposes. Exclusion criteria regarding the prototype evaluation included having a history of migraine, epilepsy, motion-sickness, severe visual or motor impairment, or being unable to wear the Head-Mounted Display (HMD).

In total, two psychologists, a psychiatrist, nurse specialist, and psychomotor therapist participated. The participants were all female, had mean age of 37 (±10.3) years and worked on average since 9.8 (±7.2) years in addiction care. The technology experience rating (by using a 7-point Likert scale) indicated a high computer (5.20 ±1.1) know-how compared to a medium videogame (3.20 ±1.5), as well as low IVR (2.40 ±1.1) and dialogue system (1.80 ±0.8) knowledge. Most of the experts (*n* = 3) had previous experience with IVR for addictive disorders from prior research projects of our group.

# Materials

## Theoretical Persuasive System Design

We started our design of the IVR peer pressure simulation for people with MBID and AUD by conducting a theoretical analysis of the persuasion context, by defining the intent, event, and strategy as described by the PSD model [18, 23]. With this, we created our PSD template (Table 1), by integrating design principles for primary task support (i.e. simulation, rehearsal, tunneling, self-monitoring), dialogue support (i.e. social role), and social *influence* (i.e. social facilitation, normative influence).

Regarding primary task support, our IVR provides experience to patients by simulating human-human interactions, allowing to link cause and effect of different social scripts for alcohol refusal under peer pressure. Further, it allows to repeatedly rehearse trainings through enactment and multisensory experiences. As dialogue support, the ECA simulates a friend to build rapport with the patient and exert interpersonal influences. This should boost the implemented social influences to drink during gatherings. The intended route to persuasion may be described as indirect, targeting emotions, habits, as well as normative and interpersonal influences using a narrative (simulation). Lastly, a dialogue UI serves as primary task support feature, by tunneling through the ECA dialogue while providing self-monitoring feedback for a better refusal skills acquisition. As described by the PSD model [23], we treat reciprocity as user characteristic that is targeted by the persuader's appeals.

**Table 1.** Theoretical Persuasive System Design: The IVR peer pressure simulation for people with MBID and AUD.

| PSD category | Design principles | Application level | Implementation |
|---|---|---|---|
| Primary task support | Simulation | IVR prototype | Simulation of human-human persuasion to enable the observation of cause and effect in realistic settings using narratives. |
| | Rehearsal | IVR prototype | Rehearsing refusal strategies with virtual agents through enactment and multisensory experiences in IVR. |
| | Tunneling | Dialogue interface | Dialogue UI guides users through refusal script training with virtual agents in a narrative manner. |
| | Self-monitoring | Dialogue interface | Dialogue UI provides traffic light feedback when selecting refusal answers to observe riskiness levels, helping to learn proper behavior. |
| | *Tailoring* | *Tailoring interface* | *Tailoring UI allows customizing the simulation to user's needs.* |
| Dialogue support | Social role (Likability, similarity) | Virtual agents | Virtual agents emulate interpersonal relationship (friendship) with user to increase the persuasive power of the ECA (e.g. interpersonal influences). |
| Social *influence*[1] | Social facilitation | Virtual agents | Friend group collectively shows drinking behavior, indicating that others are performing the habit along with the user. |
| | Normative influence | Virtual agents | Friend group with ECA elicits normative (peer) pressure to drink alcohol during social gatherings. |

[1] Original 'social *support*' may be misleading, hence changed to 'social *influence*'. Abbreviations: ECA = Embodied Conversational Agent, UI = User Interface.
[2] Implemented after our expert-based evaluation.

## Hardware and ECA prototype

To demonstrate the IVR prototype, we utilized an Oculus Quest 2 HMD with 6 degrees of freedom, 1832 x 1920 pixels per eye (rendering resolution 3456 x 1744), 80 Hz refresh rate, about 90-degree field of view, touch controllers, and a suitable laptop ( Core i7-10875H CPU, 16 GB RAM, NVIDIA GeForce RTX 2080 Super) with Oculus Link (via USB 3.1 cable).

For our persuasive ECA, we implemented the customizable Unity Multipurpose Avatar 2 (UMA2) and seated the model within the user's social space (i.e. 2m). We implemented a dialogue system using the Agents United Dialogue Platform (i.e. dialogue manager, including generation of behavior markup language (BML)) [69], multimodal BML realizer Artificial Social Agents Platform (ASAP) [70, 71], and related ASAP-Unity Bridge [72]. This encompassed Microsoft's Text-to-Speech (TTS) engine (i.e. Dutch Frank) with body language (i.e. lip sync, gestures, gaze), partially scripted using the WOOL platform (i.e. gesture, gaze) [69], with gestures and posture animations by using Unity's build-in Mecanim system. For user input, we decided to integrate a dialogue UI instead of automatic speech recognition to avoid usability issues, given that the reliability of speech-to-text engines remains troublesome. Hence, we provided buttons with selectable refusal responses based on the identified utterances during our co-creation. Upon selection, a narrator TTS (i.e. Flemish Bart) was utilized to express selected refusal responses for the user to attain a more natural dialogue flow.

## Measures

For our co-creation, we specified brainstorming missions to direct the expert's attention to three prototype components (1) IVE, (2) ECA appearance, and (3) persuasive dialogue. For the (1) IVE, we asked '*In what contexts do patients with MBID and AUD face persuasive attempts by another person to drink together?*' to identify the five most significant settings for people with MBID and AUD. Regarding the (2) ECA, we asked '*How should the persuader in the context of [outcome (1)] look like?*' to identify appearance (e.g. look, age, gender, body shape, clothing, and culture) and character trait requirements for the most significant social setting. For this, experts were also asked to rapid prototype an ECA by using a paper-based template with crayons. Lastly, for the (3) persuasive dialogue, we asked '*What are typical arguments of the persuader*?', '*What are typical appeals to emotion of the persuader?*', and '*What are good, fair, or bad coping reactions by the patient based on the identified appeals'* to construct the ECA interaction. We primarily used the collaboration platform Miro to collect our data.

For the prototype evaluation, we created a semi-structured focus group with six questions to explore the (1) first impression, persuasive ECA (i.e. (2) user experience, (3) persuasive mechanisms, and (4) persuasive power), (5) immersion procedure for people with MBID and AUD, and (6) expert's intention to use the IVR system in the clinical practice. To support recall, we used a paper-based template to note down experiences and observations during the try-out .

## Procedure

For the co-creation and evaluation, all participants were thoroughly informed, signed the informed consent, and completed a demographic questionnaire. Ethical approval was given by the University of Twente's ethics committee (ID: RP 2021-154) and care institution's scientific board. After welcoming participants to the focus group sessions, the audio, screen, and video recordings were started. For the co-creation, the researcher explained brainstorming rules and introduced the specific mission for the given focus group. For initial insights into the background and technology, a presentation was shown during the first focus group. In the following two sessions, experts were reminded to adhere to rules and the background was briefly repeated.

For the prototype evaluation, another focus group with the same experts was held 16 weeks later. We invited participants in groups of two to evaluate and observe the prototype with the IVR apparatus alternately. First, one participant was introduced to the HMD and controllers, while the other one received a paper-based template for taking notes by observing the participant and IVR. Then, a tutorial was conducted to train interactions, by letting the participant use teleport locomotion, customize the virtual hand's skin tone, and experience the dialogue UI in the same IVE but without agents and alcohol cues present. Upon completion, experts were immersed into the enriched IVE via verbal storytelling and asked to engage in a dialogue with the ECA by selecting refusal responses on the related UI. Finally, experts were asked five questions using the implemented VAS (related to cravings, ECA persuasiveness, presence, anthropomorphism, and perceived safety) integrated for subsequent patient evaluations. Then, experts alternated, and the procedure was repeated. Upon completion, a focus group was held with all experts using Microsoft Teams to discuss the user experience and related implications.

## Data analysis

We used the qualitative data collected from the experts, based on the filled-in digital and paper-based templates, as well as audio and screen recordings to identify design requirements for our IVR prototype. Further, the audio transcript from the expert focus group was analyzed based on Braun and Clarke's thematic analysis [73]. Coding was applied to the transcribed verbatim to identify themes by conducting a recursive process, using Atlas.ti (v. 9.1.6). The coding process was continuously discussed among the researchers (SL, JN, and RK) to improve the theme differentiation and eliminate inconsistencies within the analysis.

# Results

In the following parts, we describe our (A) findings from the co-creation with experts in addiction care, and (B) prototype development and expert evaluation to further improve IVR prototype and procedures.

## (A) Findings from the co-creation with experts in addiction care

The following sections described the findings from our co-creation with experts per design component: (1) IVE, (2) ECA, and (3) dialogue, before transitioning to the initial prototype development and subsequent evaluation for further improvements.

### *(1) Identifying the persuasion context and cue reactivity IVE design*

In the first focus group, experts agreed on the five most significant risk settings in which people with MBID and AUD are persuaded toward alcohol use: (1) Visiting a friend at home with multiple friends, (2) at home of family members with addiction, (3) invitation by acquaintance into a small bar or street café, (4) outside on the street with other user(s), and (5) party with many people where drinks are served by default. Design insights for (1) were further explored and included a small apartment with kitchen and living room in a Dutch social housing district. The apartment should be designed dark, noisy, and messy. The living room should contain a TV streaming a soccer match, couch, loud Dutch music, and a table with snacks, bottles (with falling over noises), and cigarettes or shag. Multiple intoxicated friends should sit on the couch under the influence of alcohol, holding a beer and/or cigarette, talking loudly (e.g. laughing, shouting), asking to drink or provide beer to the patient by default.

### *(2.1) Designing a persuasive agent to elicit peer pressure*

In the second focus group, experts defined the ECA requirements in the paramount persuasion context of *Visiting a friend at home with multiple friends*. For the ECA to be persuasive, participants described a middle-aged (30-40 years), white male with average morphological characteristics (i.e. body shape, height, body hair, relaxed posture) and slight paunch. Appearance characteristics include short, unkempt blonde or brown hair and an (week old) unshaved beard. The clothing includes a (too) large black T-shirt (incl. brand name), black or grey jogging pants, and sneakers. Other properties named were a small tattoo on the arm, holding a cigarette and beer can/bottle from (low-priced) domestic breweries. Here, besides the detailed description of the look and personal attributes, experts reported that the ECA should be realistic but not too sophisticated regarding personal attributes when no ECA-related customization (i.e. based on user input) possible. The ECA should have a nonchalant, slightly bent posture and amicable personality when sitting on the couch next to the patient.

### *(2.2) Constructing a persuasive dialogue with related refusal responses*

In the third focus group, experts reported on persuasive utterances for the dialogue, given the setting and ECA design. Before persuading the patient toward drinking, ice-breaking and rapport building methods should be implemented, such as greetings (e.g. *'Hey, nice that you are here'*), questions about well-being (e.g. *'How are you?'*), or providing comfort (e.g. *'Get out of your coat and make yourself at home'*). As hypothesized, ECA utterances should comprise primarily appeals to emotion (e.g. *'You used to be much more sociable'* ) and habits (e.g. *'That is what you always do'*) in contrast to logic/reason. Further, based on identified persuasive attempts, experts reported on low (e.g. *'No man, I stopped'*), fair (e.g. *'Not now'*), and high-risk (e.g. *'Yes, one will be okay'*) refusal responses.

## (B) Prototype development and evaluation – Towards an IVR peer pressure simulation

Following the three focus groups, we developed a prototype based on the identified requirements. In the following sections, we describe our initial design, prototype evaluation with the experts, and refined simulation based on the evaluation outcomes.

### *Initial prototype design based on the co-creation with experts*

Based on the co-creation, the IVR simulation was developed and implemented into the IVR interaction framework (Figure 3): For the (1) IVE, we designed a small apartment (Figure 3A-B) with kitchen and living room in a Dutch social housing layout. Moreover, we integrated elements such as a couch with friends under the influence of alcohol, a TV streaming a soccer match, and loud Dutch music via a virtual wireless speaker. To create a realistic and plausible IVE, alcohol cues (e.g. fridge, beer, wine, liquor) and related objects (e.g. cigarettes, shag with paraphernalia, darts, football emblem, flags, food) were added. Participants were able to open the fridge/cabinet and manipulate objects (e.g. darts, bottles) using predefined transform anchors toward the virtual hand. For our persuasive agent (2) we implemented an ECA into the IVR, by customizing the UMA2 model (see materials) based on the requirements. For this, we designed a male in his mid-30s with unkempt hair, week old beard, and beer in hand (Figure 3C). Moreover, we dressed the ECA with a black hoodie, jogging pants, and sneaker for a universal look. Lastly, for the dialogue (3), we implemented five consecutive levels (Appendix 1): building rapport and ice-breaking, appeal to habit, first persuasive attempt, second persuasive attempt, and closing consequence.


***Figure 3.*** The initial prototype: (A) living room with agents sitting on a couch/chair, alcohol-related cues, TV streaming soccer, and wireless speaker shuffling Dutch party music (B) small kitchen with interactable fridge to grab beer or liquor, (C) ECA persuading toward drinking, and (D) self-monitoring on dialogue UI to indicate riskiness levels of the selected refusal responses.

## *Expert-based evaluation*

After building our IVR prototype, we conducted an expert-based evaluation with the same participants. Here, six themes emerged to improve the IVR and procedures: (1) ECA design, (2) IVE immersion, (3) user-centered customization, (4) user-centered therapy, (5) behavior change support, and (6) IVR accessibility.

### ECAs to elicit peer pressure – Persuasive power through paralinguistic features and group dynamics

For the ECA design to elicit peer pressure, we identified the themes *persuasive mechanisms* and *persuasive speech*. The recognized persuasive mechanisms were mainly appeals to emotion or habit (i.e. intrusive behavior, grumbling) and normative pressure to use alcohol (*'Naja, he was going on and on the whole time […] and also saying some mean things. It's realistic I guess. I'm afraid.'* [E5]). Here, it was reported that alcohol-related cues and ECA behaviors (i.e. drinking, handing over beer) might boost the persuasiveness (*'… and I did like the fact that at one point he took sips himself.'* [E1]). In contrast, all experts perceived the ECA as unfriendly and low in persuasive power, given the (2) missing paralinguistic features (e.g. intonation) when using artificial voices. The experts reported on the need for subtle speech features to increase the ECA's power (*'That's the only thing I thought of: "well, that makes it unrealistic now". And I think that specifically intonation is very important for our group.'* [E1]). In contrast, despite somewhat unnatural behavior, experts accustomed to animations (*'… I had to get used to the woodiness a bit. But that was really just at the beginning and at some point, it's not so bad anymore, somehow.'* [E5]). Thus, persuasive power may be amplified using relational behavior, gestures, natural speech, and (intra)group dynamics (*'… and nudging each other a little bit like: "He's not using at all." … Two against one.'* [E5]).

### Immersion – Cue reactivity IVEs with high ecological validity

For the IVR immersion, all experts described a sense of presence (i.e. spatial immersion) within the IVE. Here, the experts identified several factors that contribute to immersion, focusing on (1) *IVE realism*, (2) *multimodality*, (3) *interactivity*, and (4) *narratives*. Concerning our IVR peer pressure simulation, experts described the (1) IVE as realistic (*'But also the amount of actions you could do just made it feel real, and also the mess on the table and stuff. It felt relative to other worlds I've seen less clean and artificial, so to speak.'* [E5]), though increasing the messiness (e.g. dirty spots, clothes), adding extra alcohol cues (e.g. wine, booze, crate of beer, glass with liquid inside), sounds (e.g. football match), and diverse background agents (e.g. older age, obesity) talking with audible voice, was suggested. Implementing (2) multimodal and (3) interactive experience was reported decisive (*'Yes, and it is indeed true that with the music, it helps to be highly immersed.'* [E3]), as all experts described the festive music and interaction capabilities as main factors for immersion. Yet, adding additional modalities (e.g. olfactory cues) was viewed with caution, as it might overstrain the patient (*'I must also say that there are clients to whom I have asked this during my research and who said "no, that is really too much". You really have to do it step by step.'* [E2]). Hence, allowing to tailor the experience could circumvent this issue and improve the current prototype. Further, as virtual hands customization during the tutorial was perceived as artificial, experts suggested to immerse and tailor by using a (4) narrative immersion (e.g. storytelling), starting with a tutorial to learn basic controls, followed by an invitation to a party, with transition to a dressing room allowing to customize the virtual hands and subsequent IVR training (*'… do* *that storytelling in the tutorial setting, that it is also included there. Because then you will be more immersed.'* [E3]).

### Customizing the experience – Tailoring setting, difficulty, and usage to the patient's needs

To account for the diverse needs, experts reported on the need to tailor *setting*, *difficulty*, and *therapeutic goals* within the IVE. Here, immersing the user into realistic IVEs without causing distress was highlighted (*'Because you want to give people cravings and they have to feel completely immersed into that situation, but it doesn't have to become so real that people really get into trouble.'* [E5]). Regarding the setting, experts suggested to tailor the IVE (i.e. messiness, agents, and sounds) and embedded cues (e.g. drinks) to increase the IVE's recognition for patients. Further, the difficulty should be customizable (*'I can imagine that it is the first time for clients that they do something like this, that it is already really complicated to see all those stimuli and then also to select, and well. I can imagine that it must also be easier the first time than the second time.'* [E5]), allowing to gradually increase the persuasive power and realism of the simulation, for instance related to proximal cues and normative pressure. Lastly, the experience should be tailorable to the therapeutic goals. Here, experts highlighted the need for specific goals related to the patient's needs (*'There are in fact many different goals, which as far as I'm concerned, you can link to this.'* [E4]).

### User-centered treatment – Tailoring therapy goals for patients with MBID and AUD

For a user-centered treatment, goals need to be linked to specific experiences in the IVR related to *assessment* or *treatment*. Regarding assessment, an initial exploration (i.e. craving, bodily signals) and creation of a 'crisis alert plan' based on risk situations were described. For treatment, experts suggested a related refusal skills training, for instance based on body-centered learning (e.g. bodily signals such as cravings, coping through mindfulness) or self-reflection (e.g. cause and effect), as well as confrontation tool for attitude change (e.g. for dangerous self-overestimation). In general, training should be designed for an error-free learning in people with MBID (*'… it is also important to say that clients with disabilities should initially practice error-free with maximum amount of help.'* [E5]). It should be applied from the mid till end of the treatment, as well as early stages of self-overestimation. For this, treatment protocols must be developed with therapists from various disciplines to determine why (e.g. specified goals), how (e.g. intervention, therapist support), with whom (e.g. patient, therapist involvement), and when (e.g. timing, frequency) IVR therapy should be applied.

### Behaviour change support – Stand-alone (SA-BCSS) versus therapist-delivered (VT-BCSS) interventions

Two strategies for behavior change support were identified: *stand-alone* (SA-BCSS) and *via therapists* (VT-BCSS). For SA-BCSS, summative feedback should be delivered using praise and positively framed messages, motivating for extra sessions. For formative self-monitoring feedback, experts were inconclusive on how to display it, either as constant active, after utterance selection, or deactivated, suggesting different training levels when used (*'… then indeed you get a little bit of, this is a right answer, and this is a wrong answer.'* [E3]). Here, patients should start learning with prompts for proper answers to guarantee error-free learning. Yet, all experts agreed that IVR therapy should consist of VT-BCSS using multiple sessions with trained professionals, such as psychomotor therapists (*'Yes, if you miss that then the rest doesn't make much sense, I think. Because then it becomes a bit of try and error and I think that's really very risky for this target group.'* [E5]), to learn and reflect upon bodily signals and coping. Instead of talking about past events, patients will be able to talk about the presence, making abstract concepts (such as cravings) graspable (*'You always talk about something that someone has experienced in the past, with which you try to prepare them for something again in the future. So then, your talk therapy is actually always a little bit "out of this world."'* [E5]). Here, IVR allows to replay the behavior for better reflection, possibly supported by extra materials (*'In fact, you want them to practice the situation and then you can engage in dialogues about "What happened?" and "So what did you think about that?"'* [E3]). All experts indicated great interest to explore the system in clinical practice.

### IVR usability – Facilitators and barriers for accessibility

Lastly, for an accessible IVR design, experts found three *facilitators* and *barriers*. Regarding facilitators, experts described realistic interactions, such as walking and grabbing objects and playful elements in the IVE, using the virtual hands *(The walking, you can see well, and I also liked the tutorial.'* [E1]). Here, limiting teleport locomotion to predefined anchors was not perceived as restriction, given the availability in all areas. To learn the related interaction controls, experts described the initial tutorial as crucial element. Further, the virtual hands served as visual feedback to aid button recognition (i.e. by observing the corresponding animation) and spatial understanding (*'I did like that you, so to speak, really see what you're doing when grabbing.'* [E3]). In contrast, the instructional scaffolding was described as helpful by just two experts (*'Found it useful that it was there. Just: "oh yes, that button was for grabbing." A kind of confirmation.'* [E2]), as it was not noticed by the others. Lastly, the evaluation using a VAS in the IVR was described positive, for instance as 'thermometer' to measure tensions. In contrast, experts described barriers when using text-based procedures for this group (*'… if that text written out, if that doesn't distract, in some way, from what you're doing.'* [E5]). Hence, VAS-based evaluations should avoid displaying text to the user (e.g. ask items verbally) and the ECA utterance should be removed from the UI to reduce distraction and increase font sizes for user utterances. Further, to tailor the system to the user's needs, the terminology (e.g. instructional scaffolding) should use a simple instead of abstract wording (e.g. *walk* instead of *teleport*). Lastly, experts described minor interaction barriers (e.g. opening the fridge while grabbing another object) and suggest using a buffer zone to avoid a sudden proximity to objects when teleporting to anchors (*'That's unnatural then. You stand so close; you wouldn't stand like that in real life.'* [E2]).

## *Final prototype design based on the prototype evaluation*

After the expert evaluation, we improved the prototype design and immersion procedures for people with MBID and AUD. To boost the immersion and stimulate rapport building with the ECA, we implemented a narrative immersion using storytelling instead of introducing scenes verbally. The patients start in the tutorial IVE and receive an invitation to a party in the evening (Figure 4). Users then go upstairs to a dressing room to customize the IVR simulation, such as the virtual hands (i.e. skin tone), difficulty (i.e. IVE, behavior change support), and IVE (i.e. cues, messiness, social pressure, music). Patients are then immersed to the enriched IVE, including other guests, alcohol-related cues, and related objects. For a better usability, we reduced text to a minimum, improved the terminology with simpler language, and added a buffer zone when using teleport to anchors. Further, the SA-BCSS (i.e. traffic light feedback) can be deactivated to allow for an unrestricted VT-BCSS.


***Figure 4.*** The final IVR prototype with narrative immersion: (A) friend inviting to a party this evening, (B) dressing room to customize the IVR simulation (i.e. virtual hands skin tone, difficulty, IVE), (C) IVE customization (i.e. alcohol cues, messiness, social pressure, smoking cues, music), and (D) persuasive ECA interaction using refusal responses of different riskiness levels.

# Discussion

## Principal findings

The present work reports on the co-creation of an IVR simulation to manage peer pressure in patients with MBID and AUD. Following our theoretical PSD, we conducted three focus groups with experts from an addiction clinic for our group to understand the persuasion context and establish design guidelines. Based on the findings, an IVR prototype was developed and tested with the same experts to tailor prototype and procedures to clinical needs. For the requirements, experts described the risky context of *visiting a friend at home with multiple friends* to be highly relevant during clinical treatment. To simulate interpersonal influences, we built a persuasive ECA and dialogue with refusal responses of different riskiness. After playtesting, experts reported the need for natural speech features (i.e. paralinguistics), non-verbal behavior, and group dynamics (e.g. two against one) to enhance the ECA's persuasive power. Further, facilitators (i.e. embodied interactions, tutorial, VAS) and barriers (i.e. text-based procedures, complex terminology, interaction issues) for accessibility were found. To achieve a deep immersion, narratives, realism, and interactivity were described as fundamental factors. For clinical usage, experts suggested to tailor IVE difficulty, content, and treatment goals (e.g. body-centered learning) to the patient's needs. Lastly, for behavior change support experts preferred therapists-delivered (VT-BCSS) over stand-alone interventions (SA-BCSS) to avoid a perilous trial-and-error.

For our cue reactivity IVE, we explored prevalent persuasion contexts that often cause relapse in patients with MBID and AUD, and further elaborated on the most relevant setting in clinical care to create our IVE. In doing so, we found the established need for realism, multimodality, and interactivity for deep immersion [74]. For this, we used our prior knowledge on developing IVR interactions for this group, by designing controllable and realistic IVEs, assistive embodied interactions (i.e. snap, sphere-cast), anchor-based teleportation with room-scale area, and an instructional scaffolding [60]. Previous work reported such error-free and positive user experiences as major factors leading to user satisfaction [23, 74]. Similar to our IVR, other scholars built cue reactivity IVEs for an exposure with high ecological validity [24], meaning that IVEs should be tailored to context and culture. However, to elicit realistic behavioral responses, plausible interaction with the IVE are needed [26]. By this, IVEs will be processed in a more peripheral manner and certain events happening (e.g. social interactions, music, television) will attract the patient's attention. Yet, IVE and events should match and some must be directed towards the subject for a plausible IVR [26]. Thus, compared to others, we advanced IVE interactions on the object/conversation level and developed a *simulation* (narrative) with consecutive storyline to guide patients through tutorial and refusal skills training. As in game design, this will probably increase engagement and ease rapport building with ECAs [75].

Regarding our ECA design, we specified our PSD to avoid blackboxing [76], allowing to further investigate our template for IVR peer pressure simulations, identify active PSD ingredients, and replicate findings in diverse user and application areas. For our co-creation, we specifically looked into the ECA appearance and persuasive dialogue design to connect specific design elements to our PSD. Thereby, we systematically designed for the *social role* of a virtual friend. By this, exacerbating emotional appeals should be transferred to induce lifelike emotions (e.g. guilt, fear) in patients with MBID and AUD. Prior work respective IVR for AUDs used mostly 'non-intelligent' agents as social cue [4], intended to elicit cue reactivity and enhance the IVE's ecological validity [27]. Yet, as learning paradigms appear promising for IVR addiction therapy [4], interactable and persuasive ECAs are needed to simulate peer pressure, a factor known to cause relapse in patients [2]. Here, using our IVR enables novel treatment approaches (e.g. refusal training), but also adds realism and ecological validity to existing paradigms like VRET.

Yet, our ECA was perceived as artificial and thus low in persuasive power by experts, as paralinguistic information (e.g. intonation, stress) were lacking when using TTS engines. Similar findings were observed when persuading with anger [52], though this was dependent on the power relation between ECA and subject. This is fascinating, as this power dimension appears similar to typical group dynamics in peer pressure (i.e. group leaders exhibit greater power). Therefore, one can assume that an ECA must be regarded as cognitive capable entity with social power to convey appeals to emotion/habit in IVR [46]. Besides sophisticated algorithms, this may be tackled through the body's (verbal) communication channels [77]. As described before, ECAs enable us to convey indirect peer pressure (*social facilitation*) via alcohol drinking and offering animations. Therefore, both physical communication channels, verbal and non-verbal, should be considered carefully. In this regard, *social facilitation* seems highly dependent on animations (e.g. collective drinking), while *normative influences* are mainly induced through natural speech with paralinguistics and (intra) group dynamics using multi-agent interactions (e.g. two against one). However, to elicit emotions like guilt/provoke social exclusion in patients when violating group norms [29], rapport with ECAs must be established. To achieve this, procedures should aim for a narrative-based immersion to learn controls, build rapport with the ECAs, and customize the simulation to the patient's needs using a natural flow.

For clinical usage, *tailoring* the IVR and procedures to patient's needs and goals was found decisive. Through the built-in customization options, the patient can alter IVE elements, difficulty, and their virtual skin tone, making it a personal experience. Coupled with our narrative, this allows patients to explore, engage, and interact with the peer pressure simulation. The resulting engagement represents the power of playful learning and should be further explored in IVR therapy, especially since it may be key for establishing a relationship with the ECA(s). Notable, said narrative might act as persuasive feature [78], presumably as part of the *simulation* [23], by linking cause and effect in chronological order. Prior work showed that narratives can influence behavioral intentions towards health behaviors [78]. However, findings were acquired in mostly non-manipulable mediums, hence influencing own narratives and experiencing cause and effect appears as captivating approach for effectual IVR therapies. As narratives can influence through both, direct and indirect routes [78], we consider it as engaging mechanism for behavior change in patients that hardly benefit from cognitively demanding approaches. Still, to our surprise, behavior change support should be provided via therapists (VT-BCSS) instead of stand-alone (SA-BCSS) [79, 80]. Thus, IVR should serve as tool for adjunct treatment to explore symptoms using body-centered paradigms, stimulate self-reflection, and train coping skills.

Nonetheless, as our research focused on a stand-alone approach, *self-monitoring* feedback was used to boost the patient's self-efficacy in using proper refusal skills. However, the traffic light metaphor was perceived as indicator for correctness instead of risk levels, which conflicts with an error-free learning for our group. Overall, therapists were rather inconclusive about using automatic feedback, as this is related to the envisioned goal, which as we learned can be multifaceted. During our focus group, expert input focused on therapist-delivered as opposed to stand-alone interventions, though some envisioned it as homework between therapy sessions [79]. Hence, stand-alone approaches should not be neglected in future work, as IVR therapy is often described as an adjunct treatment to existing protocols [79]. Lastly, using a VAS in the IVR appeared adjuvant to collect patient data (e.g. cravings, anxiety) without breaking immersion [68], for instance to develop a crisis-alert-plan. Yet, the development of treatment protocols, feedback provision, and collection/processing of data during IVR trainings constitute important future research areas to design an effective IVR therapy for vulnerable groups with AUD [68].

Similar findings were reported by Skeva et al. (2021), who surveyed practitioners and scholars on their view on IVR for additive disorders, showing that IVR could add to the clinical practice trough diverse usage possibilities. Notable, said experts also described the gain of self-efficacy during relapse prevention training as key factor for control in reality [79]. Further, peer pressure via agents (or avatar embodiment) was named as vital ingredient for learning with high ecological validity [79], mainly for socially-accepted substances, such as alcohol, nicotine, and (for us) cannabis. In detail, the need to practice exact words for saying 'no' was reported, matching our focus on refusal scripts for specific risk situations. However, *rehearsal* may be refined by letting subjects express the utterance themselves instead of using a narrator, while keeping the TTS for accessibility. Yet, Skeva and colleagues findings on IVR therapy emphasized cognitive-behavioral practitioners, though particularly vulnerable groups could benefit from body-centered paradigms. In our work, we found that disciplines would use this tool differently [79], for instance with focus on bodily signals during psychomotor therapy. Thus, future research should create IVR therapy protocols using interdisciplinary teams to establish a taxonomy with pedagogical learning goals for vulnerable people [4, 81].

## Limitations

The findings of this study have to be seen in light of some limitations: First, we co-created our IVR prototype by involving specialized professionals from an addiction clinic, therefore, perception in patients with MBID and AUD might differ, given the preconditioned behavioral pattern in AUDs. Hence, patient evaluations are required to validate the ECA's persuasiveness, including replication studies using our template. Our PSD enables scholars to develop similar experiences through an analogous user-centered design, using our accessible IVR interaction, ECA architecture, narrative procedures, and VAS-based evaluation procedure. Moreover, scholars should learn from our unimplemented requirements, such as (intra) group dynamics (e.g. multi-agent scenarios) and natural speech with paralinguistics to establish persuasive power in peer pressure simulations. Secondly, we have not yet explored ECA animations in a systematic manner. Instead, we used animations for a natural interaction. Hence, non-verbal communication (i.e. indirect social influences) forms a promising factor for *social facilitation*/*normative influence* that should be addressed in future research, although it was not missed by our experts. For this, scholars should consider facial expressions [52], gaze, and gestures, presumably combined with natural speech to create plausible interactions [26].

# Future work

Future work should clarify factors contributing to ECAs' persuasive power for IVR peer pressure simulations. Our findings suggest that paralinguistic, nonlinguistic, and non-verbal information form key elements for persuasion in patients with MBID and AUD. Hence, subtle emotional expressions, along the verbal appeals, seem to take a crucial role for persuasion using virtual humans in our group, which connotes to further explore interpersonal (e.g. rapport, group dynamics) and empathetic (e.g. facial expressions, social touch) behavior along the aforestated information via natural speech. For an initial rapport building with the ECAs, integrating narratives seems auspicious, for instance by playing short games with ECAs before starting refusal trainings. Therefore, future research with patients should be performed to further explore specific PSD elements and validate the IVR for future research, in particular to develop therapy protocols with interdisciplinary teams. This is an essential step to grasp the full prospect of IVR for addiction medicine, as current applications do not use the full potential IVR has to offer. Though therapists reported VT-BCSS as critical behavior change support for our group, we suggest to also explore how feedback can be conveyed using IVR's multisensory capabilities, for instance by using haptics to indicate riskiness when conversing with ECAs. By this, researchers can avoid influences on a simulation's ecological validity, with discrete, body-centered feedback that may enhance learning outcomes in patients with MBID and AUDs. Further, olfactory cues could be integrated for additional difficulty and patients could read out loud selected utterances for a better internalization. Finally, peer pressure via ECAs embedded in IVR should be studied more comprehensively to grasp their power in influencing humans toward negative behavior, including the potential usage for therapy, ethics to adhere to, and possible negative effects on therapy adherence (within outpatient settings).

# Conclusion

Our findings establish a PSD for IVR peer pressure simulations in patients with MBID and AUD. By using an analogous design approach, researchers can replicate findings and explore effective PSD features for persuasive ECAs. Throughout our co-creation with experts, we learned that appeals to emotion/habit should be conveyed via natural human speech channels (i.e. verbal and non-verbal) to guarantee sufficient persuasive power in ECAs. For this, subtle emotional information must be provided via paralinguistics in the ECA's speech (e.g. intonation), gestures (e.g. handing over beer), and interpersonal dynamics (e.g. group formation, rapport effects). However, concerning behavior change support, the experts favored therapist-delivered (VT-BCSS) instead of stand-alone interventions (SA-BCSS) to avoid a perilous trial and error. Thus, future work should further investigate factors contributing to persuasive power in virtual humans, such as emotional information in speech and non-verbal expressions to create realistic peer pressure simulations. Finally, research with interdisciplinary teams should be conducted to establishing IVR therapy protocols with specific pedagogical learning goals for vulnerable patients.

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# Conflicts of interest

None declared.

# Abbreviations

ASAP: Artificial Social Agents Platform
AUD: Alcohol Use Disorder
BCSS: Behavior Change Support System
SA-BCSS: Stand-Alone Behavior Change Support System

VT-BCSS: Via Therapist Behavior Change Support System
BML: Behavior Markup Language
ECA: Embodied Conversational Agent
HMD: Head-Mounted Display
IQ: Intelligence Quotient
IVE: Immersive Virtual Environment
IVR: Immersive Virtual Reality
MBID: Mild to Borderline Intellectual Disability
PSD: Persuasive System Design (model)
TTS: Text-to-Speech
UI: User Interface
UMA2: Unity Multipurpose Avatar 2
VAS: Visual Analogue Scale
VRET: Virtual Reality Exposure Therapy
XR: eXtended Reality

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**Appendix 1.** Persuasive dialogue and coping strategies sing tunneled behavioral feedback in a traffic light manner.