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Flavien Ehret

fehret@etu.uqac.ca

Université du Québec à Chicoutimi

Yannick Francillette

Université du Québec à Chicoutimi

Bob-Antoine J. Menelas

Université du Québec à Chicoutimi

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From Cue Exposure to Situated Action: Immersive, Embodied, and Socially-Oriented Technologies for Alcohol Use Disorder.

Flavien Ehret, *University of Quebec at Chicoutimi (UQAC), Chicoutimi, Canada*
 fehret@etu.uqac.ca ORCID 0000-0001-6227-1314

Yannick Francillette, *University of Quebec at Chicoutimi (UQAC), Chicoutimi, Canada*
 yannick_francillette@uqac.ca ORCID 0000-0002-4315-1955

Bob-Antoine J. Menelas, *University of Quebec at Chicoutimi (UQAC), Chicoutimi, Canada*
 bamenela@uqac.ca ORCID 0000-0001-9027-4352

Abstract—Alcohol use disorder (AUD) is a persistent public-health problem in which craving and relapse in high-risk situations are central processes. Cue exposure and relapse prevention are well established, but their clinical impact is limited by weak ecological validity, modest engagement, and uncertain transfer to everyday life. Virtual reality (VR) is increasingly used to present alcohol-related cues and social situations, to rehearse coping, and to assess craving, yet most systems still treat the user as a passive recipient of cues.

This narrative review synthesizes research on immersive, embodied, and empathy-oriented technologies for AUD across addiction science, human-computer interaction, psychology, and digital health. Organizing the evidence around VR cue exposure, embodied action and agency, serious-game and experiential-learning mechanisms, coping rehearsal, and social cognition, we identify a recurring conceptual shift: from exposure as passive presentation to exposure as situated action, in which users enact protective behaviors, negotiate social pressure, and rehearse adaptive responses within ecologically rich yet safe environments.

The evidence base remains heterogeneous, and real-world transfer is the field's central open question. Immersive, embodied, and empathy-oriented systems are therefore best understood as promising experimental tools and adjuncts to established psychosocial treatments rather than as standalone validated interventions. We close with a research agenda for mechanism-focused and longitudinal evaluation, standardized measurement of embodiment, agency, presence, and empathic response, and translational work on ethical design and integration into care pathways.

Index Terms—alcohol use disorder, virtual reality, serious games, empathy, embodied interaction, human-computer interaction

I. INTRODUCTION

A. Context and Motivation

Alcohol use disorder (AUD) is a persistent and heterogeneous condition with substantial health, psychological, social, and economic consequences. Its effects extend beyond alcohol consumption itself and may involve emotional regulation, interpersonal relationships, social participation, occupational functioning, and the ability to respond adaptively when alcohol is available or socially encouraged. The course of AUD may also involve repeated attempts to reduce alcohol consumption, periods of remission, treatment disengagement, and episodes

of resumed consumption. These characteristics make AUD an important public-health challenge and support the development of interventions addressing the contextual, cognitive, emotional, behavioral, and social processes associated with alcohol use [1], [2].

Craving is one of the central processes considered in the understanding and management of AUD. It broadly refers to a subjective urge or desire to consume alcohol, whose intensity, duration, and expression may vary across individuals and situations. Craving does not occur independently of context. It may be elicited or intensified by the perception of alcoholic beverages, places previously associated with drinking, negative emotional states, stress, interpersonal conflict, or social pressure [3]–[5]. Bars, restaurants, parties, supermarkets, and domestic environments may therefore function as configurations of interconnected cues rather than as neutral physical settings. Visual, auditory, olfactory, spatial, affective, and social information can combine within these situations and contribute to the difficulty of implementing an adaptive response [5], [6].

Research on virtual environments for AUD has shown that immersive representations of alcohol-related situations can be used to elicit and assess craving under controlled conditions. The literature has notably examined situations involving alcohol-related objects, drinking environments, and interpersonal pressure. These findings support the ecological relevance of representing craving as a situated response involving more than the isolated presentation of an alcoholic beverage [4], [5], [7]–[9].

Non-pharmacological interventions for AUD encompass behavioral, cognitive, motivational, educational, and psychosocial approaches. Cognitive-behavioral interventions may, for example, help individuals identify internal and external triggers, recognize high-risk situations, examine maladaptive thoughts, and develop strategies for managing craving and social pressure [3]–[5]. Depending on the situation, coping may involve refusing an offered drink, leaving or modifying an environment, redirecting attention, regulating negative emotions, recalling personal objectives, seeking social support, or selecting an alternative behavior [3], [10].

The practical value of these strategies depends not only on whether they can be understood or recalled in an educational

or therapeutic setting, but also on whether they can be implemented when a high-risk situation actually occurs. Knowing how one should respond does not necessarily imply that the appropriate response will be initiated when alcohol-related cues, craving, stress, social expectations, and limited decision time are experienced simultaneously. This distinction creates a potential gap between declarative knowledge about coping and the capacity to perform a coping response under situated cognitive and emotional demands.

Conventional verbal explanations, worksheets, static media, and role-playing activities can support reflection and skills acquisition. However, these methods may provide limited opportunities to reproduce and control the dynamic, spatial, multimodal, and socially situated properties of everyday alcohol-related situations. Conversely, practicing directly in real drinking environments would be difficult to standardize and could expose participants to unnecessary risks. A major design challenge is therefore to create realistic and repeatable situations in which users can experience contextual demands and rehearse adaptive responses while maintaining sufficient experimental, technical, and ethical control.

Digital interventions provide several possible ways of addressing this challenge. Mobile applications, websites, interactive programs, serious games, and immersive systems can support self-monitoring, personalized feedback, educational activities, cognitive-behavioral exercises, and the practice of responses to alcohol-related situations. Previous reviews suggest that digital and immersive interventions show promise as adjuncts to conventional AUD treatment, although their effects are typically modest and the evidence remains heterogeneous [5], [11], [12].

Among these technologies, virtual reality (VR) is particularly relevant because it enables the controlled simulation of situations that may be difficult, costly, or unsafe to reproduce in the physical world. Immersive systems can present alcohol-related objects, locations, sounds, social encounters, and contextual variations while allowing researchers to control the sequence, duration, and intensity of the experience. Compared with isolated images or videos, VR can situate alcohol-related cues within coherent, spatially organized, and first-person environments.

Recent reviews indicate that the principal applications of VR to AUD have concerned cue-reactivity assessment, craving induction, and virtual reality cue-exposure interventions. Alcohol-related virtual environments have been used to represent bars, restaurants, parties, domestic environments, and other situations associated with drinking. Across these studies, VR appears capable of eliciting subjective craving under controlled conditions. However, the available evidence remains heterogeneous because studies differ in their populations, virtual environments, exposure procedures, interaction techniques, number of sessions, comparison conditions, and measurement instruments [7]–[9].

Taken together, the available literature provides stronger evidence for the capacity of VR to represent alcohol-related situations and elicit cue-reactive responses than for its long-term therapeutic effectiveness. Recent reviews also identify methodological limitations concerning sample sizes, standard-

ization, objective measurement, follow-up assessments, and the evaluation of transfer to everyday behavior [7]–[9].

More importantly from an HCI perspective, VR has frequently been conceptualized primarily as a medium for presenting alcohol-related cues. Within this paradigm, users encounter virtual bottles, drinking environments, or social offers, while craving constitutes one of the main outcomes measured during or immediately after exposure. This use of VR is valuable for examining cue reactivity and supporting exposure-based approaches. Nevertheless, presenting a high-risk situation is not equivalent to enabling the user to act meaningfully within it.

When interaction is limited, an immersive environment may reproduce the perceptual characteristics of a risky situation without enabling users to practice the behavioral, cognitive, and interpersonal responses required to manage it. For example, observing a virtual character offering alcohol differs from having to interpret the character's intention, formulate a response, physically reject the offer, select an alternative drink, leave the situation, or seek support. The difference concerns not only the quantity of interaction, but also the role attributed to action in the learning process.

This observation motivates a transition from *exposure within an immersive environment* toward *active and embodied engagement with an immersive situation*. Active interaction refers here to the user's ability to make choices, manipulate relevant objects, communicate with virtual characters, implement coping strategies, and observe the consequences of these actions. Embodied interaction further recognizes that perception and cognition are connected to sensorimotor activity, spatial position, bodily representation, and the user's sense of agency within the virtual environment.

From this perspective, VR is not merely a display technology used to surround the user with alcohol-related stimuli. It becomes an interactive medium through which users can rehearse situated responses and construct knowledge through experience. This orientation is consistent with Action-Centered Exposure Therapy (ACET), which proposes moving beyond passive exposure by integrating purposeful action into the confrontation with alcohol-related situations [13].

Serious-game design offers a complementary structure for organizing these interactive experiences. Goals, rules, challenges, feedback, progression, and meaningful consequences can transform a virtual scenario into a structured learning activity. In an AUD-related system, game mechanics may organize repeated practice across varied situations and make relationships among cues, decisions, coping strategies, and consequences more explicit. Serious-game mechanisms may also contribute to engagement and persistence, which are important considerations for digital interventions [14].

Nevertheless, gamification should not be understood as the simple addition of points, rewards, scores, or entertainment features. In a transformational perspective, game design should connect the intended player transformation with the target audience, its context, the anticipated barriers to change, and the experience through which this transformation may occur [15]. Accordingly, the relevance of ludic elements depends on their alignment with the intervention objectives, interaction

design, and characteristics of the intended users.

In the context of AUD, this alignment requires particular caution. Poorly designed mechanics could trivialize the condition, prioritize in-game performance over reflection, or generate engagement without supporting the intended learning process. These possibilities are treated here as design risks rather than as empirically established effects. The central question is therefore not whether an AUD intervention should be made "fun" but how ludic structures can support attention, agency, experimentation, feedback, and reflective learning without undermining the seriousness of the condition.

The challenge addressed by immersive interventions is also fundamentally social. Alcohol consumption frequently occurs in interpersonal situations involving invitations, expectations, social norms, conflict, encouragement, rejection, assistance, or pressure. An alcohol-related environment cannot therefore be reduced to a collection of physical cues. Virtual characters, their verbal and nonverbal behavior, their emotional expressions, and their relationship with the user can influence the meaning and difficulty of the situation.

This social dimension connects immersive intervention design with research on social cognition. Social cognition encompasses several processes involved in perceiving, interpreting, and responding to other people, including emotion recognition, attribution of intentions, perspective-taking, theory of mind, and empathy. These processes may be relevant to AUD because difficulties in interpreting social information or responding appropriately to interpersonal situations could affect relationships, social support, and the management of situations involving alcohol.

Empathy is generally conceptualized as a multidimensional construct. Cognitive empathy refers broadly to the capacity to understand another person's perspective or mental state, whereas affective empathy concerns responses to another person's emotional experience. Although related, these dimensions should not be treated as interchangeable [16].

A meta-analysis reported lower overall empathy in individuals with AUD than in healthy controls. Analyses distinguishing empathy dimensions indicated significantly lower cognitive empathy in the AUD groups, whereas the difference in affective empathy was not statistically significant [16].

More broadly, research conducted with populations affected by AUD has reported differences across several components of social cognition, including emotion recognition, theory of mind, and empathy [17], [18]. These findings nevertheless require cautious interpretation because the observed patterns vary across social-cognitive components, tasks, populations, comorbidities, and measurement instruments. Moreover, many commonly used tasks rely on static or decontextualized stimuli and may have limited ecological validity [17].

In immersive systems, empathy-related processes may be explored through interaction with virtual characters, perspective-taking, changes in embodied viewpoint, narrative choices, and representations of the consequences that alcohol-related decisions may have for other people. Such mechanisms could support the interpretation of social signals, reflection on interpersonal consequences, or the perceived significance of virtual social encounters. These possibilities must nevertheless

be framed as design hypotheses rather than as established therapeutic effects. Indeed, a meta-analysis found a statistically significant effect of VR on perspective-taking, but not on empathy as a broader outcome [19]. A subsequent systematic review found that affective-empathy effects tended to be temporary, whereas improvements in cognitive empathy were more likely to persist across the follow-up periods examined [20].

Immersion alone should therefore not be assumed to produce empathy. An emotionally intense experience may generate distress, identification, sympathy, or presence without necessarily producing an accurate understanding of another person's perspective. Empathy-oriented experiences may also introduce ethical risks, including guilt induction, stigmatization, stereotyping, emotional manipulation, or excessive distress. Their evaluation should therefore distinguish empathy from immersion, identification, emotional intensity, sympathy, perspective-taking, and prosocial intention.

These questions establish the HCI and computing orientation of the present review. Evaluating an immersive system for AUD cannot be limited to determining whether the environment elicits craving. It also requires examining how the system mediates perception, bodily action, decision-making, social interaction, and learning. Relevant dimensions include usability, accessibility, interaction clarity, presence, social presence, embodiment, agency, engagement, acceptability, cybersickness, emotional safety, and the compatibility of the proposed interactions with users' needs and abilities.

These dimensions must also remain conceptually distinct from clinical effectiveness. A technically functional and usable system is not necessarily therapeutically effective. Similarly, a system that elicits presence, craving, or emotional engagement does not necessarily improve coping, reduce alcohol consumption, or facilitate the transfer of learning to everyday life. Feasibility, usability, user experience, proximal psychological responses, skills acquisition, transfer, and clinical outcomes consequently represent different levels of evaluation.

From this perspective, the central question is no longer only whether VR can reproduce alcohol-related cues. This capacity is already documented in the literature. The broader challenge is to determine how immersive and game-based technologies can move beyond cue presentation to support active, embodied, socially situated, and potentially transferable learning. Addressing this challenge requires connecting bodies of literature that are often considered separately: VR cue exposure, coping-skills training, serious games, experiential learning, embodied interaction, empathy, social cognition, and HCI evaluation.

B. Scope of the Review

This evidence-based narrative review examines immersive and interactive technologies relevant to the assessment and non-pharmacological support of AUD. Its primary focus is on fully or substantially immersive VR systems involving alcohol-related situations, cue exposure, active interaction, embodied action, coping-skills practice, serious-game mechanisms, virtual social interaction, empathy, and social cognition.

Studies involving participants formally diagnosed with AUD are considered alongside selected studies involving hazardous, problematic, or heavy alcohol use when their technological or methodological contributions are directly relevant to immersive-intervention design. These populations are not treated as clinically equivalent, and differences in participant characteristics are considered when interpreting the reported findings.

The review adopts an interdisciplinary perspective at the intersection of HCI, immersive-system design, serious games, psychology, and addiction research. Clinical findings are considered insofar as they clarify the phenomena that interactive systems seek to represent, assess, or support. However, this review does not provide clinical treatment recommendations and does not assume that technological feasibility constitutes evidence of therapeutic effectiveness.

Particular attention is given to the distinction among:

- assessment of craving or cue reactivity;
- induction of craving under controlled conditions;
- passive or minimally interactive cue exposure;
- active and embodied exposure;
- rehearsal of coping strategies;
- serious-game and experiential-learning mechanisms;
- empathy-oriented and socially situated interaction;
- evaluation of usability, user experience, and technical feasibility;
- evaluation of transfer and clinical outcomes.

The review also distinguishes among documented empirical effects, theoretical mechanisms, design implications, and prospective research directions. The capacity of VR to induce craving, presence, or emotional engagement is not treated as evidence that it improves coping, empathy, abstinence, or behavior outside the virtual environment. Claims concerning transfer are considered only when studies include outcomes extending beyond the immediate immersive experience.

The scope excludes interventions based exclusively on pharmacological treatment, non-immersive digital applications with no direct conceptual relevance to immersive interaction, and systems designed solely for general alcohol education without an interactive or experiential component. Research on other substance-use disorders is considered selectively when it provides transferable knowledge concerning exposure, embodiment, coping practice, social interaction, serious-game design, or HCI evaluation. Evidence from other disorders is not assumed to generalize automatically to AUD.

This article is an evidence-based narrative review rather than a systematic review or meta-analysis. Its purpose is to connect relevant bodies of literature, clarify concepts, compare technological paradigms, and identify research and design gaps. It does not claim exhaustive coverage and does not provide pooled estimates of clinical effectiveness. The process used to identify, select, and organize the literature is described in Section II.

C. Guiding Questions

Building on this conceptual orientation, the review is structured around the following questions:

- 1) **Immersive exposure:** How has VR been used to represent alcohol-related cues, environments, and situations for the assessment or management of craving?
- 2) **Active and embodied interaction:** To what extent do existing systems enable users to act within alcohol-related situations rather than remain primarily exposed to them?
- 3) **Coping and experiential learning:** How can immersive interaction and serious-game mechanisms support the situated rehearsal of coping strategies, decision-making, and reflection?
- 4) **Empathy and social cognition:** How are empathy, perspective-taking, emotion recognition, theory of mind, and social interaction conceptualized, implemented, and measured in immersive systems relevant to AUD?
- 5) **HCI evaluation:** Which usability, user-experience, presence, embodiment, agency, social presence, accessibility, comfort, and safety dimensions are relevant to the evaluation of these systems?
- 6) **Transfer and evidence:** What evidence supports the transfer of coping, social, or empathic learning from virtual environments to real-world situations, and which methodological limitations currently restrict such conclusions?

Together, these questions organize the review around a progression from the presentation of alcohol-related cues to situated action, social interaction, and potential transfer. This progression does not imply that active, game-based, or empathy-oriented systems are inherently superior to established approaches. Rather, it provides an analytical framework for examining what current technologies enable, what outcomes have actually been evaluated, and which claims remain theoretical or insufficiently supported. Figure 1 summarizes this organizing structure: the four design mechanisms that immersive systems for AUD combine, the human–computer-interaction dimensions along which they are most often evaluated, and the real-world transfer question that remains the field’s central open problem.

II. METHODS

A. Narrative Review Design

This article adopts a narrative review design to integrate heterogeneous evidence from human–computer interaction, immersive technologies, serious games, psychology, addiction research, and digital health. The aim is to clarify key concepts, technological approaches, and evaluation practices relevant to immersive interventions for alcohol use disorder (AUD), rather than to estimate pooled effect sizes or conduct a formal risk-of-bias assessment.

1) *Information Sources and Search Strategy:* Literature was identified through structured database searches combined with backward and forward citation chaining. Databases were selected to cover the disciplinary scope of the review: PubMed for clinical and addiction-medicine literature; IEEE Xplore and ACM Digital Library for human–computer interaction, virtual-reality engineering, and human-factors work; Scopus and Web of Science for cross-disciplinary coverage of serious games, gamification, and social cognition; and Google Scholar

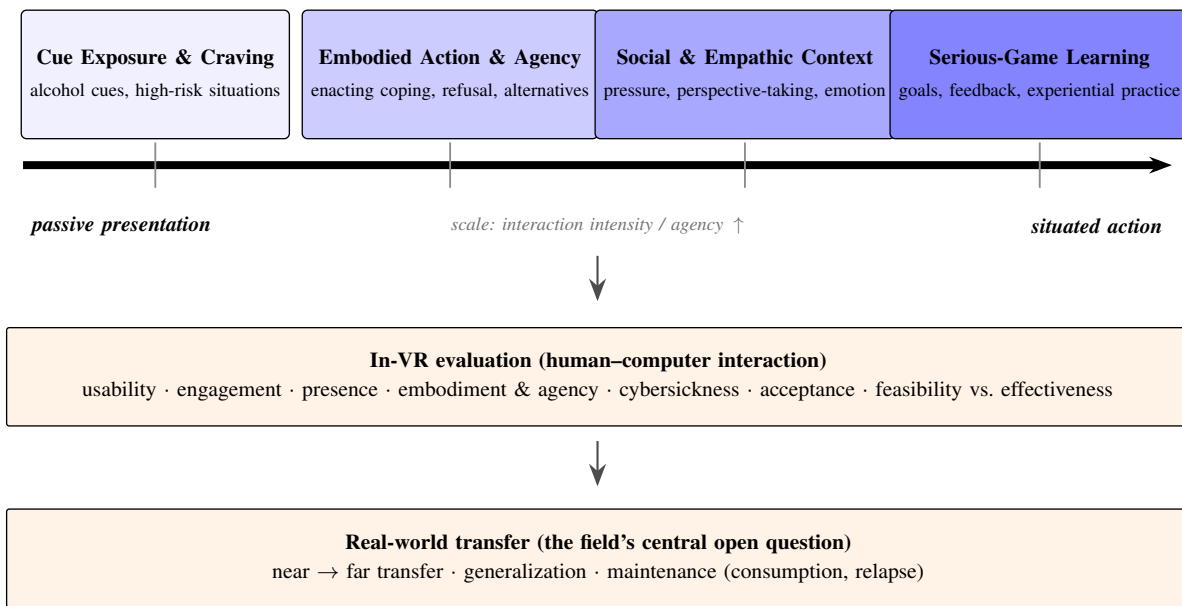


Fig. 1. Conceptual organization of the review. Top: the four design mechanisms that immersive, embodied, and empathy-oriented systems for AUD combine, ordered along a passive-to-active scale (from passive cue presentation to situated, action-based engagement). Middle: the human-computer-interaction dimensions along which these systems are most often evaluated inside the virtual environment. Bottom: the real-world transfer of learning to everyday behavior, which remains the field's central open question. The figure is a conceptual synthesis of the review's structure; it does not represent an empirical causal model, nor an evidence hierarchy: the passive-to-active ordering is a design space rather than a therapeutic progression.

for citation snowballing. French-language academic literature was additionally searched through HAL and the Cairn index. Institutional sources (e.g., WHO, NIAAA, and national health agencies) were consulted for epidemiological context and clinical guidance, rather than as primary evidence.

Searches were conducted intermittently between 2021 and 2026, reflecting the evolving nature of immersive technologies and digital health. The corpus was frozen for analysis in June 2026, and additional checks were performed in August 2026 to ensure that key publications from 2025 to 2026 were included.

The review focuses on publications that are conceptually relevant rather than on a strict chronological cut-off. Consequently, the corpus includes recent work (up to 2026) and older, foundational references from the late twentieth century, as well as earlier conceptual or theoretical contributions when necessary.

Keyword families were organized around the four thematic clusters of the review. For immersive cue exposure and craving induction, terms combining “virtual reality” or “immersive environment” with “alcohol use disorder”, “alcohol dependence”, or “substance use disorder”, and with “craving”, “cue exposure”, or “exposure therapy”. For serious games and experiential learning: “serious game”, “game-based”, “gamification”, “experiential learning”, and “motivation”. For embodiment and presence: “embodiment”, “spatial presence”, “immersion”, and “cybersickness”. For empathy and social cognition: “empathy”, “theory of mind”, “social cognition”, and “perspective taking”. French-language equivalents (e.g., “réalité virtuelle”, “jeu sérieux”, “addictions”) were used in the HAL and Cairn searches. Full keyword sets per cluster, together with example Boolean chains, are provided in Appendix A.

In addition, key review articles and protocols on VR in

addiction, mental health, and healthcare were used as entry points for citation snowballing [9], [12], [21], [22], along with foundational HCI reviews on constructs such as social presence [23]. Reference lists of these publications and of influential HCI and serious-game papers were screened to identify further relevant work.

2) Eligibility Criteria: The review prioritized peer-reviewed journal articles and conference papers reporting empirical studies, technical systems, or conceptual frameworks related to:

- immersive or game-based technologies applied to alcohol use disorder or substance use;
- VR or serious games in mental health with direct relevance to craving, cue reactivity, coping, or experiential learning;
- empathy, social cognition, embodiment, or presence in immersive environments where concepts can inform AUD-related interventions.

When examining clinical outcomes such as craving reduction, relapse-related indicators, or treatment adherence, studies conducted with participants diagnosed with Alcohol Use Disorder were given precedence. Evidence from broader substance use or mental health populations was incorporated primarily to inform conceptual and design dimensions (e.g., embodiment, presence, empathy, experiential learning), without inferring direct clinical transferability to AUD unless explicitly supported by the original authors. This distinction is maintained throughout the review to minimize overgeneralization while situating AUD within the wider context of immersive digital health research.

Searches were conducted in English and French (the latter via HAL and the Cairn index); the retained corpus is nevertheless predominantly in English, with a smaller set of French-language clinical and institutional sources. Conference proceedings and

study protocols were eligible when they provided unique information on system design or emerging methodological trends, even in the absence of final clinical outcomes [21]. Theses, non-peer-reviewed reports, and purely commercial materials were excluded unless they offered essential technical detail that could not be found elsewhere; such cases are explicitly signalled when cited.

3) *Study Selection and Thematic Grouping*: Titles and abstracts were screened to exclude clearly irrelevant records (for example, non-interactive pharmacological trials or VR applications unrelated to health or behavior change). Full texts were then examined for studies that:

- include an interactive or immersive component (e.g., VR, AR, serious game, exergame);
- address alcohol or substance use, craving, coping, or related psychological constructs; or
- contribute to the conceptual understanding of embodiment, presence, empathy, or experiential learning in ways that can be reasonably connected to AUD.

Because this is a narrative rather than systematic review, no formal flow diagram or numerical accounting of records is provided. Exact counts of records identified, screened, and retained were not tracked prospectively and would be unreliable if reconstructed post hoc. Instead, the synthesis is organized around four thematic clusters derived iteratively from the literature:

- 1) immersive cue exposure and craving induction;
- 2) serious games and experiential learning for addiction and mental health;
- 3) embodiment, agency, and action-centered coping practice;
- 4) empathy and social cognition in immersive environments.

Within each cluster, studies are discussed in terms of their technological design, target constructs, measurement strategies, and reported outcomes or limitations. Stronger or more recent studies are highlighted where appropriate, but the narrative approach does not claim exhaustive coverage of all available work.

4) *Corpus Characteristics*: The final corpus is dominated by small-sample exploratory studies and protocol papers, with relatively few large randomized controlled trials specifically targeting alcohol use disorder. Most VR-based craving and cue-exposure studies involve between 10 and 60 participants, often recruited from treatment settings or university populations, and focus on short-term outcomes such as subjective craving, physiological reactivity, or task performance. Serious-game interventions in mental health and addiction similarly tend to report pilot or feasibility studies rather than long-term follow-up on consumption or relapse.

In addition to these empirical reports, the corpus includes several conceptual and theoretical papers on embodiment, presence, empathy, and experiential learning in immersive environments. These works are used to structure the conceptual framework of the review and to motivate the research agenda, but they are not treated as direct evidence of clinical efficacy in AUD.

5) *Methodological Positioning*: The reporting follows general recommendations for narrative reviews in interdisciplinary

fields, emphasizing transparency about search strategy, eligibility criteria, and thematic synthesis without adopting PRISMA or other protocols designed for systematic reviews and meta-analyses [24], [25]. Claims are limited to what is supported by the cited literature, and areas of uncertainty, conflicting findings, or limited evidence are explicitly identified in the Discussion and Limitations sections. Large language model assistance was used for language editing and drafting support; all scientific content, claims, and citations were produced and verified by the authors.

6) *Limitations of the Review*: Several limitations of the review method should be acknowledged. First, the search strategy was not based on a pre-registered protocol, and no formal flow diagram or prospective tracking of record counts was maintained. As a result, the corpus cannot be claimed to be exhaustive, and some relevant studies, particularly in adjacent areas such as general addiction, anxiety disorders, or non-immersive digital interventions, may have been missed.

Second, the review is restricted primarily to peer-reviewed publications in English (and, to a lesser extent, French), which introduces potential language and publication biases. Grey literature, theses, and commercial descriptions of digital tools were generally excluded, except when they provided technical details that could not be obtained from peer-reviewed sources.

Third, no standardized risk-of-bias tool or quality-rating scheme was applied to individual studies. Instead, methodological robustness is appraised qualitatively (in the spirit of scales designed for narrative reviews such as SANRA [26]) based on sample size, study design, ecological validity, and clarity of reporting. Stronger or more recent studies are highlighted where appropriate, but the narrative synthesis does not assign formal evidence grades.

Finally, the thematic clustering and emphasis reflect the specific focus of the doctoral project on immersive, action-centered, and empathy-related approaches for AUD. This means that some strands of the broader literature on digital health, serious games, or virtual reality may be under-represented if they do not directly inform this focus. The review should therefore be interpreted as a conceptual and integrative synthesis and a research agenda, rather than as a definitive quantitative summary of all available evidence.

III. EVIDENCE MAP AND THEMATIC OVERVIEW

Here, we provide a descriptive overview of the corpus and the main lines of evidence for each theme; the full thematic synthesis (representative studies and examples, main reported outcomes, recurring methodological limitations, and implications for AUD research and design) is consolidated in Table III (Appendix B). The aim is not to quantify effect sizes, but to make explicit which kinds of interventions, populations, and constructs are represented, and where evidence is sparse or predominantly conceptual. The four themes (immersive cue exposure and craving induction; serious games and experiential learning; embodiment, agency, and coping; and empathy and social cognition) are used as an organizing frame.

The evidence map highlights an uneven distribution of robust data across the four themes. Immersive cue exposure and

craving induction are supported by the most directly AUD-related empirical work, including several dedicated trials and systematic reviews. In contrast, serious games, embodiment and agency, and empathy-oriented designs are primarily informed by pilot studies, non-clinical samples, or broader mental health and addiction contexts. For these latter themes, the review therefore treats the available literature mainly as a source of conceptual and design principles, rather than as established evidence of clinical efficacy in AUD. The following sections unpack each theme in more detail, distinguishing between what is empirically supported in AUD and what constitutes a prospective research agenda.

IV. ALCOHOL USE DISORDER AND NON-PHARMACOLOGICAL INTERVENTIONS

A. *Craving, High-Risk Situations, and Relapse*

Alcohol use disorder is heterogeneous in its manifestations, severity, and course. Difficulties associated with AUD cannot be reduced to the quantity or frequency of alcohol consumption. They may also involve impaired control, persistent use despite adverse consequences, recurrent craving, and difficulties adapting behavior in situations where alcohol is available or socially encouraged [1], [2].

Craving, as defined in Section I-A, is a central target in non-pharmacological interventions for AUD [3]–[5]. In the present section, its functional role is the point of interest: craving is a situated response that emerges from the interaction among individual characteristics, affective states, learned associations, and contextual information, and intervention approaches are organized around anticipating, tolerating, or responding to the situations in which it occurs.

High-risk situations similarly involve more than the physical presence of alcohol. They may include interpersonal pressure, conflict, social celebrations, negative emotional states, habitual routines, or environments in which alcohol consumption has previously occurred. The significance of a cue consequently depends on the situation in which it is encountered and on the meaning attributed to it by the individual.

From an interaction-design perspective, this situated character of craving suggests that an intervention should not represent risk exclusively through static images or isolated virtual objects. It may also need to represent the spatial, social, emotional, and behavioral conditions in which decisions about alcohol are made. This interpretation constitutes a design implication derived from the literature rather than an established clinical effect.

Relapse-prevention perspectives emphasize the importance of identifying high-risk situations and developing responses that can be mobilized when these situations occur. Resumed alcohol consumption should not be interpreted solely as the consequence of insufficient motivation or individual failure. It may instead reflect the interaction among cue reactivity, emotional states, social influences, coping resources, and the individual's perceived ability to manage the situation [3].

This distinction is important for immersive-system design. A system may successfully induce craving or reproduce a recognizable drinking situation without helping the user respond

to that situation. Craving induction, assessment of cue reactivity, coping-skills practice, and relapse prevention should therefore be treated as related but distinct intervention objectives.

For clarity, we distinguish four related but non-equivalent objectives: (a) inducing craving or cue reactivity, (b) assessing these reactions, (c) training coping skills within a given situation, and (d) supporting transfer of these skills to everyday life. An immersive system may address one or several of these objectives, but they should not be conflated when interpreting outcomes.

B. *Cue Exposure and Cognitive-Behavioral Approaches*

Cue-exposure approaches are based on the controlled presentation of stimuli associated with alcohol use. These stimuli may include visual representations of alcoholic beverages, drinking-related sounds, environmental contexts, or social situations involving alcohol. Exposure can support the observation of subjective and behavioral responses to such cues and has been used in virtual environments to elicit craving under standardized conditions [4], [5], [7], [8].

The capacity to elicit craving is particularly relevant for assessment because responses can be examined without reproducing alcohol consumption itself. Virtual environments can also provide greater contextual richness than photographs or isolated laboratory stimuli by representing locations, objects, sounds, and social interactions within a coherent situation. However, the capacity of an environment to induce craving does not by itself demonstrate that exposure produces therapeutic benefits.

Cognitive-behavioral approaches address relationships among situations, thoughts, emotions, physiological responses, and behavior. In the context of AUD, they may help individuals identify triggers, recognize high-risk situations, examine alcohol-related expectations, and develop alternative responses. These approaches also emphasize the acquisition and rehearsal of skills that can be used when craving or social pressure occurs [3], [10].

Cue exposure and cognitive-behavioral training can be conceptually distinguished by the role assigned to the user. Exposure primarily organizes contact with relevant stimuli, whereas skills training requires the user to select, perform, and evaluate a response. Action-centered exposure frameworks make this distinction explicit by combining cue exposure with the performance of contextualized coping actions in virtual environments [13]. An immersive intervention may combine these functions, but their presence should be documented separately when describing or evaluating the system.

This distinction also prevents the term *interactive* from being used too broadly. Looking around an environment, moving through a scene, or selecting a menu option provides a degree of interaction, but does not necessarily constitute therapeutic action. Interaction becomes more directly connected to coping when it requires the user to respond meaningfully to the represented risk situation.

C. *Coping Strategies and Relapse Prevention*

Coping refers to the cognitive, emotional, behavioral, and interpersonal responses used to manage demanding situations.

In AUD-related contexts, coping strategies may target craving itself, the situation producing it, or the individual's interpretation of that situation. The relevance of a strategy may vary according to the context, the intensity of craving, the availability of social support, and the individual's objectives and previous experience [3], [10].

Behavioral strategies may include refusing an offered drink, leaving or modifying a high-risk environment, selecting a non-alcoholic alternative, engaging in another activity, or contacting a supportive person. Cognitive and emotional strategies may involve redirecting attention, reconsidering alcohol-related expectations, recalling personal objectives, tolerating an urge without acting on it, or regulating the negative affect associated with the situation [3].

Interpersonal coping is particularly important when alcohol use is embedded in social interaction. Refusing alcohol may require not only knowledge of an appropriate response, but also the ability to recognize social pressure, communicate a decision, maintain that decision when challenged, and manage the emotional consequences of the exchange. Such situations involve social cognition, verbal and non-verbal communication, perceived self-efficacy, and context-sensitive decision-making.

For immersive-system design, coping should consequently be represented as an action performed within a situation rather than as abstract information presented outside that situation. A virtual scenario could, for example, require the user to identify a risk, choose among possible responses, perform the selected strategy, and receive feedback about its immediate consequences. This is a prospective design principle and should not be interpreted as evidence that such a scenario improves real-world coping [13].

Repeated practice may allow users to encounter variations of a similar problem, such as alcohol offers expressed with different levels of insistence or craving experienced in different environments. Variation is relevant because successful performance in one standardized scenario does not necessarily indicate that the same response can be adapted to other situations.

Feedback is another potentially important component of coping-skills training. It may clarify the relationship among the user's decision, the action performed, and the resulting changes in the virtual situation. Nevertheless, feedback should remain aligned with the intervention objective. Scores or rewards alone do not demonstrate that an appropriate coping strategy has been understood or acquired.

D. Limits of Conventional Training and Transfer

Conventional interventions can use discussion, written materials, role-playing, therapist-guided exercises, or retrospective analysis of high-risk situations. These methods provide important opportunities for reflection and skills acquisition. However, the conditions in which a skill is learned may differ substantially from the conditions in which it must later be applied.

A participant may be able to describe an appropriate coping strategy during a clinical or educational session while experiencing difficulty implementing it in the presence of craving, emotional distress, environmental cues, or social

pressure. Knowledge of a strategy, performance during a structured exercise, and spontaneous use in everyday life therefore represent distinct levels of learning and evaluation.

Immersive environments may help reduce part of this contextual gap by placing skills practice within spatially, perceptually, and socially organized situations. Their potential contribution lies not simply in presenting more realistic stimuli, but in allowing users to perceive a situation, make a decision, perform an action, and observe its consequences. This potential must nevertheless be empirically evaluated rather than inferred from immersion alone [13].

Whether coping skills rehearsed in such environments transfer to everyday situations is addressed in Section XI, where the evidence remains limited and methodologically heterogeneous and where robust assessment requires longitudinal and behavioral evaluation beyond the immediate session.

The central design challenge is consequently not to reproduce everyday life in every detail, but to identify which contextual and interactive properties are necessary for meaningful practice. Excessive realism may increase technical complexity or emotional burden without improving learning. Conversely, insufficient contextual information may prevent users from recognizing when and how a strategy should be applied.

From a human-computer interaction perspective, these observations motivate the design of immersive systems in which alcohol-related situations are represented not only as stimuli, but as interactive contexts for decision and action. The present work therefore focuses on how virtual environments can be structured to support situated coping practice, while remaining compatible with clinical frameworks for AUD.

These limitations motivate the examination of virtual reality as a medium for controlled, situated, and interactive practice. The following section therefore reviews how alcohol-related cues and craving have been represented, induced, and assessed in immersive environments, while maintaining a clear distinction between cue reactivity, active skills training, transfer, and clinical effectiveness.

V. VIRTUAL REALITY, ALCOHOL CUE EXPOSURE, AND CRAVING

A. Virtual Environments for Cue Presentation

Virtual reality (VR) has been widely used to present alcohol-related cues in controlled yet ecologically oriented environments. Early and subsequent systems typically recreate bars, pubs, parties, restaurants, domestic spaces, and outdoor locations associated with drinking, while manipulating the presence or absence of alcoholic beverages, social interactions, and contextual elements such as music or ambient noise [27]. These environments are designed to approximate real-world situations in which alcohol is available or socially encouraged, but within a framework that allows researchers to regulate exposure.

Within this paradigm, VR is conceptualized primarily as a medium for cue presentation. Users are immersed in spatially organized scenes using head-mounted displays, and may experience the environment from a first-person perspective. Alcohol-related stimuli include visual representations of bottles,

glasses, cans, and alcoholic drinks placed on tables or in refrigerators, shelves of alcohol in supermarkets, and signage or decoration typical of drinking venues [5], [28]. Contextual cues may comprise lighting, background noise, music, and the layout of the environment, while social cues are often represented through avatars who drink, talk, or offer alcohol [4], [29].

The technical affordances of VR allow these stimuli to be embedded within coherent scenes rather than presented as isolated images or videos. Compared with non-immersive materials, VR environments can integrate visual, spatial, auditory, and social information into a single experience [27]. This integration supports the representation of craving as a situated response to a configuration of cues, rather than as a reaction to a single object. From an HCI perspective, however, immersion and spatial coherence do not automatically entail active or embodied interaction. In many studies, participants primarily observe the environment or navigate passively without performing contextually meaningful actions.

B. Craving Induction and Assessment

A substantial body of work has examined the use of VR to induce and assess alcohol craving. Across multiple studies and reviews, exposure to alcohol-related virtual environments reliably increases subjective craving compared with neutral or control scenes, both in heavy social drinkers and in individuals with alcohol use problems [5], [27]. Participants typically report higher craving scores when immersed in bars, pubs, or parties where alcohol is visible and accessible, relative to environments without alcohol cues or with neutral content.

VR-based craving assessment often relies on self-report measures collected before, during, or after exposure. Common procedures include repeated ratings of craving intensity on visual analogue scales or standardized questionnaires, allowing researchers to track fluctuations over the course of a session [27]. In some studies, physiological indicators such as heart rate, skin conductance, or gaze patterns have been explored as complementary measures, although these remain less standardized and are not consistently reported [27]. The controlled nature of VR exposure facilitates comparisons between cue-rich and neutral conditions, as well as the examination of specific stimulus components.

Experimental designs vary in their structure. Some studies expose participants to a single alcohol-related environment, while others systematically manipulate parameters such as the density of alcohol cues, the presence of social characters, or the level of environmental realism [4], [29]. These manipulations provide insights into the relative contribution of individual cues and contextual dimensions. Nevertheless, the diversity of populations, procedures, measurement instruments, and analysis methods limits direct comparability across studies, a point emphasized in recent systematic reviews [7].

Taken together, the available evidence supports the capacity of VR to elicit cue-reactive craving responses under controlled conditions. This capacity, however, concerns proximal psychological responses during or immediately after exposure. It does not in itself establish long-term therapeutic effects or behavioral

change outside the virtual environment. Distinguishing craving induction and assessment from coping-skills training, transfer, and clinical outcomes is therefore essential for interpreting the role of VR in AUD interventions [7], [27].

C. Contextual and Social Alcohol-Related Situations

Beyond the presence of alcoholic beverages, VR environments can represent the broader situational context in which alcohol use occurs. As noted in Section IV-A, craving is modulated not only by alcohol-related objects but also by location, atmosphere, interpersonal interactions, and perceived expectations [3], [5]; the distinctive contribution of contextual VR exposure is that these situational factors can be instantiated, varied, and controlled experimentally.

Several VR studies explicitly integrate social pressure and interpersonal dynamics into exposure scenarios. For example, systems have been developed in which avatars offer alcoholic drinks, encourage consumption, or otherwise exert social influence on the participant [4], [29]. These scenarios allow researchers to examine how social pressure interacts with alcohol cues in shaping craving. In patients with alcohol dependence, exposure to alcohol-rich environments is often sufficient to elicit high craving, whereas social pressure may differentially affect craving in social drinkers [4]. Such findings underscore the importance of considering both individual characteristics and situational properties.

Contextual variation has also been used to explore differences in craving across environments. Some studies compare pub-like scenes with domestic settings or outdoor locations, while others manipulate the emotional or sensory tone of the environment [5], [30]. These designs aim to capture the heterogeneity of real-world high-risk situations, reflecting that craving may arise in multiple contexts, including social gatherings, solitary drinking, and everyday routines such as grocery shopping. From a design standpoint, this heterogeneity raises the question of which contextual features are necessary to evoke recognition and engagement without overwhelming the user.

The ability of VR to combine spatial, sensory, and social information offers a powerful medium for representing the complexity of alcohol-related situations. At the same time, most existing systems still emphasize exposure to cues and situations more than the user's active role in managing them. In many protocols, users observe drinking behaviors, face social offers, or navigate through environments, but are not required to perform coping actions, make decisions with consequences, or practice alternative responses. This observation motivates the transition discussed in later sections from passive or minimally interactive exposure toward active, embodied, and socially situated interaction [13], [27].

D. Therapeutic Applications of Virtual Exposure

Virtual reality cue-exposure therapy (VRCET) has been explored as a potential adjunct or alternative to conventional interventions for alcohol use. Building on principles of exposure and habituation, these approaches aim to reduce cue reactivity and craving by repeatedly presenting alcohol-related stimuli in

controlled conditions, sometimes in combination with cognitive-behavioral strategies [7], [27]. Protocols typically involve multiple sessions in which participants are immersed in alcohol-related environments while guided to tolerate craving or to apply coping techniques.

Systematic reviews focused on alcohol use have synthesized the results of studies employing VR-based exposure [7]. Overall, VR appears capable of reliably provoking craving, and some studies have reported short-term reductions in craving following repeated exposure or improvements relative to conventional exposure. However, the evidence remains heterogeneous and is limited by small samples, diverse populations, varying numbers of sessions, and differences in outcome measures. Importantly, many studies focus on immediate or short-term effects, with relatively few including longer-term follow-up or behavioral outcomes such as relapse rates or changes in real-world consumption [7].

Some interventions integrate VR exposure with coping-skills training, for example by combining cue-rich environments with therapist guidance, cognitive restructuring, or role-played refusal skills [4]. In such cases, VR serves not only as a medium for exposure, but also as a context for practicing specific responses. Nonetheless, the documentation of interaction design is often limited, making it difficult to determine the extent to which users are actively engaged in decision-making and action versus primarily exposed to stimuli.

From an HCI and computing perspective, these therapeutic applications highlight both the promise and the current constraints of VR. The capacity to standardize scenarios, control exposure parameters, and integrate multisensory information offers clear advantages over purely imaginal or non-immersive methods. At the same time, methodological limitations and variability in implementation caution against treating VR exposure as an established standalone treatment for AUD. Existing evidence supports feasibility and proximal psychological effects more strongly than long-term clinical effectiveness [5], [7], [27].

E. Limits of Passive Cue Exposure

Despite its strengths, passive or minimally interactive cue exposure in VR presents several limitations that are particularly salient from an HCI and learning perspective. First, observing alcohol-related stimuli without meaningful action restricts the opportunities for users to practice adaptive responses. Watching avatars drink, seeing bottles on shelves, or hearing offers may induce craving, but does not necessarily train the skills required to manage such situations, such as refusal, substitution, leaving the environment, or seeking support [13], [27], [31]. The distinction between exposure and coping-skills training is therefore critical.

Second, interaction in many studies is limited to low-level actions such as looking around, moving through the environment, or selecting options via simple input devices. While these actions confer a degree of agency, they do not necessarily constitute therapeutic behavior. Without embodied, task-relevant interaction, such as physically rejecting an offer, choosing an alternative drink, or helping another character,

users may remain primarily spectators of risk situations rather than active participants in their management [13]. This limitation constrains the potential for experiential learning.

Third, passive exposure tends to simplify social contexts. Virtual environments may represent social pressure through scripted avatar behaviors or standardized offers, but cannot capture the full complexity of interpersonal dynamics, including subtle cues, negotiation, and the interplay between long-term relationships and momentary decisions. As a result, users rehearse responses to stylized situations rather than to the nuanced social interactions encountered outside the laboratory [4], [29]. While such scenarios are valuable for experimental control, their ecological validity for social coping remains partial.

Fourth, the available evidence for VR cue exposure is stronger for craving induction and short-term reductions than for generalized coping improvements, abstinence, or relapse prevention. As discussed in Section XI, limitations in sample sizes, control conditions, standardization, and follow-up assessments constrain stronger claims about long-term clinical benefits [7], [27].

Finally, passive cue exposure provides few opportunities to evaluate transfer, since measures typically focus on proximal responses during the session [27], [31]. As discussed in Section XI, claims regarding transfer from virtual exposure to real-world behavior therefore remain speculative and require different outcome measures [7].

These limitations do not undermine the value of VR for cue reactivity assessment or as a component of exposure-based interventions. Rather, they delineate the boundary of what passive exposure can reasonably achieve and highlight the need for systems that move beyond cue presentation toward active, embodied, socially situated, and empathy-aware interaction. The subsequent sections therefore examine immersive interventions that incorporate serious-game mechanisms, experiential learning, and socio-emotional dimensions, and discuss how these paradigms may complement traditional exposure approaches within a rigorously evaluated framework.

VI. FROM PASSIVE EXPOSURE TO ACTIVE AND EMBODIED INTERACTION

A. Active Interaction in Immersive Environments

Most virtual reality systems for alcohol use have so far emphasized cue presentation rather than active, goal-directed interaction. Users are typically immersed in bars, parties, or domestic scenes where bottles and glasses are visible, but their role is largely to observe, navigate, and report craving [5], [27]. This configuration is aligned with traditional cue exposure paradigms, yet it offers limited opportunity to rehearse the concrete actions required to manage high-risk situations.

From a human-computer interaction perspective, active interaction denotes that the system responds contingently and meaningfully to the user's input: manipulating objects, moving through space to perform tasks, selecting among alternatives, or engaging with social characters in ways that influence the unfolding scenario. Serious-game approaches illustrate this shift by embedding alcohol-related stimuli within missions or

objectives that require action under constraint, such as locating and neutralizing bottles in a supermarket or responding to offers in a bar [13]. In such designs, exposure is no longer purely observational; it is structured as a sequence of decisions and actions that can support experiential practice of coping behaviors.

B. Embodiment and Body Ownership

Active interaction is closely connected to embodiment, understood as the integration of perception and action through a situated body in the environment. In immersive VR, embodiment is supported when visuomotor contingencies are coherent: the user's movements are tracked and mapped onto a virtual body or hands in real time, creating a sense of body ownership and agency over actions [32]. These sensorimotor properties are not merely aesthetic; they shape how situations are experienced and how actions are learned.

In the context of alcohol use disorder, craving and relapse involve bodily sensations, motor tendencies, and action preparation, not just abstract cognitions. Embodied interaction may therefore be more appropriate than purely symbolic or point-and-click interfaces for rehearsing responses to alcohol-related cues. Reviews of VR in addiction have highlighted VR as an "embodied technology" that can modify the feeling of presence and support naturalistic behaviors within simulated environments [33], [34]. However, embodiment itself is a design condition rather than a guarantee of therapeutic effect. It may increase experiential salience and self-relevance of coping actions, but these benefits must be demonstrated empirically rather than inferred from presence alone.

C. Agency and Consequential Decision-Making

A core distinction between passive exposure and active learning is agency: the sense that one can initiate actions that have recognizable consequences. In many VR exposure studies, agency is limited to looking around or moving through the environment, while the key therapeutic process remains habituation to cues [27]. Serious-game and interaction-centered approaches propose to extend this by requiring users to take consequential decisions, accepting or refusing a drink, staying in or leaving a context, protecting another character, or choosing a coping strategy under social pressure [13].

When the system responds to these decisions with observable outcomes, such as changes in the social situation, feedback from characters, or progression in the scenario, it creates a microcosm in which the consequences of alternative behaviors become concrete. Game-based interventions for alcohol and tobacco, for example, have asked participants to hit or avoid substance-related images, reporting decreases in craving and increases in self-efficacy during the intervention period [35]–[37]. These studies suggest that consequential decision-making and action may contribute to perceived control, but the mechanisms linking in-game agency to out-of-game behavior remain under-characterized.

D. Enaction and Action-Centered Exposure

Building on enactive approaches to cognition, Action-Centered Exposure Therapy (ACET) proposes to move beyond passive cue presentation by embedding purposeful action within alcohol-related situations [13], [38]. From this perspective, virtual environments are not merely contexts for perceiving alcohol cues, but settings in which users must decide, act, and experience the consequences of their behavior [38].

In ACET-inspired scenarios, therapeutic goals are operationalized as situated actions rather than as purely declarative instructions. Examples include refusing a drink offered by a social agent, removing alcohol products from shelves, or assisting distressed characters instead of joining in drinking [13]. Such action-oriented tasks embody coping strategies in concrete behavioral sequences, allowing patients to rehearse alternative responses within controlled yet ecologically valid situations.

From an enactive standpoint, these designs illustrate a shift from exposure as mere cue confrontation towards exposure as the practice of situated, embodied decision-making. In the context of AUD, emerging VR interventions increasingly incorporate such action requirements, asking users not only to endure alcohol-related cues but also to negotiate social pressure, manage their bodily engagement, and enact coping responses in real time. Although the empirical evidence for long-term clinical benefits remains limited and heterogeneous, these action-centered, socially situated scenarios exemplify how immersive environments can operationalize enactive principles by tightly coupling perception, motor activity, and affective appraisal within ecologically meaningful alcohol-related situations.

E. Enactive and Situated Perspectives

The move toward active and embodied interaction aligns with enactive and situated accounts of cognition, which emphasize that knowledge and skills emerge through ongoing coupling between perception, action, and environment [39], [40]. In this view, learning is not limited to acquiring declarative information; it involves developing usable responses within concrete situations. For alcohol use disorder, this perspective is salient, since drinking behavior is shaped by social contexts, routines, affective states, and environmental constraints.

Immersive technologies are particularly suited to enactive and situated approaches because they can recreate structured situations that require interpretation and action. Rather than isolating a bottle or glass from its context, VR can present a constellation of cues, location, atmosphere, social pressure, emotional tone, within which the user must act. Action-centered exposure therapy (ACET) for AUD explicitly builds on this idea by placing the patient at the center of a task that must be performed under exposure, thereby transforming cue contact into a context for strategic action [13]. Similar logic underlies VR-assisted cognitive-behavioral therapy, where coping skills are trained in lifelike scenes designed to reflect patients' personal risk situations [41], [42].

F. Rehearsal of Coping Strategies

A key implication of active, embodied, and situated interaction is the potential to use VR as a medium for rehearsing coping strategies rather than solely inducing or extinguishing craving. Coping in alcohol-related situations involves responses such as attentional redirection, cognitive reappraisal, refusal, avoidance, and help-seeking. These behaviors are difficult to train through exposure alone because they depend on timing, context, and execution under affective load. VR can render these strategies practiceable by embedding them in scenarios that simulate high-risk situations while remaining repeatable and controllable.

Game-based ACET prototypes and VR training systems have, for instance, required users to actively reject drinks, remove alcohol from shelves, or assist distressed characters, with the aim of reconditioning automatic responses and reinforcing alternative behaviors [13], [38]. Likewise, VR-CBT protocols have combined cue-rich scenes with therapist-guided coping tasks, such as implementing refusal scripts or using grounding techniques during social pressure [31], [42]. These interventions illustrate how coping strategies can be operationalized as interactive tasks; the experiential-learning logic underlying such task-based rehearsal is developed in Section VII-C. However, the evidence that such rehearsal produces durable changes in everyday behavior or reduces relapse rates remains limited and often constrained to short-term follow-up [43], [44].

G. Current Evidence and Research Gaps

The current literature indicates that active and embodied interaction is conceptually promising for AUD interventions, but empirical support is still uneven. Most studies on alcohol-related VR focus on cue reactivity, craving induction, and short-term exposure-based effects [5], [7], [27]. In comparison, relatively few works systematically investigate how interaction design, task structure, embodiment level, social dynamics, feedback, modulates coping practice, self-efficacy, or transfer to daily life.

Several gaps can be identified. First, interaction is often under-specified: many systems describe environments in detail but provide limited information on what users can actually do, beyond navigation and simple selection. This makes it difficult to differentiate between passive exposure, minimally interactive experiences, and genuinely action-centered interventions [13]. Second, evaluation frequently relies on subjective craving or presence measures, with less attention to usability, behavioral performance, perceived self-efficacy, or long-term consumption and relapse outcomes [7]. Third, high immersion and presence are sometimes implicitly equated with therapeutic potential, although systematic reviews caution that compelling experiences do not automatically translate into better clinical results [27], [31].

At the same time, emerging work on VR-based cognitive-behavioral therapy and serious games for AUD suggests that integrating exposure with coping rehearsal and game mechanics may enhance engagement and perceived control [13], [35]–[37], [41]. These interventions are still in early stages, and the parameters that optimize learning (frequency and variability of

practice, difficulty progression, feedback, and personalization) remain to be established. For the field to progress, future studies will need to document interaction design more explicitly and adopt outcome measures that reflect coping and transfer. They will also need to situate VR not as a standalone solution but as a medium for operationalizing established psychosocial approaches within experiential, embodied, and socially rich environments.

VII. SERIOUS GAMES AND EXPERIENTIAL LEARNING

A. Serious Games in Health and Addiction Research

Serious games are digital games designed with a primary purpose other than entertainment, such as education, training, or rehabilitation [45]. In this article, we use *serious games* to refer to the designed artifacts and *transformational games* to refer to games explicitly intended to produce behavioral or cognitive change in the player [15]. We use *game-based interventions* to refer to the clinical deployment of such games within structured treatment protocols for AUD. In health contexts, they have been used to promote physical activity, support motor rehabilitation, train cognitive skills, and deliver psychoeducational content, often with the dual aim of increasing engagement and supporting behavior change [46]–[48].

In the field of addiction, serious games have been explored both as prevention tools for young populations and as adjunctive interventions in treatment. Scoping and systematic reviews report applications targeting alcohol, tobacco, and other substances, typically aiming to increase risk awareness, modify cognitive biases, or support coping skills [49], [50]. Some games focus on knowledge and risk awareness, presenting scenarios that illustrate the consequences of substance use and encouraging reflection about choices and outcomes [49]. Others target more specific mechanisms such as attentional bias, inhibitory control, or coping skills by embedding therapeutic exercises in a game-like format [35]–[37].

For alcohol use disorder in particular, serious games and interactive simulations have been used to support cue refusal, decision-making in high-risk situations, and the rehearsal of alternative behaviors during simulated social encounters. Examples include training games that expose players to panoramic alcohol-related scenes and require them to make adaptive choices under time pressure [37], as well as action-centered exposure prototypes that integrate cue exposure with task performance and coping practice [13]. These systems illustrate how game-based formats can operationalize therapeutic principles such as cue exposure, cognitive restructuring, and coping rehearsal within structured interactive experiences.

Although existing studies report promising effects on proximal outcomes such as craving reduction, self-efficacy, or knowledge acquisition during or shortly after gameplay [36], [46], [49], the evidence for long-term changes in consumption or relapse rates remains limited and heterogeneous. As discussed in Section XI, longitudinal evidence on durable behavioral effects is still lacking; serious games in addiction should therefore be considered as experimental or adjunctive components that operationalize psychosocial principles, rather

than stand-alone replacements for established treatments [48], [49].

B. Game Mechanics and Therapeutic Objectives

From a human-computer interaction perspective, a serious game is not defined only by its theme but by the structure of its mechanics: objectives, rules, choices, feedback, progression, and consequences [51]–[53]. Aligning these mechanics with therapeutic objectives is essential to avoid a mismatch between what the player does in the game and the skills that the intervention aims to support [47].

Therapeutic objectives in alcohol use disorder often include recognizing risk situations, managing craving, refusing drinks, seeking support, and reflecting on the impact of one's behavior on oneself and others [54], [55]. Game objectives can make these targets concrete by turning them into tasks: identifying and neutralizing alcohol-related objects, resisting offers from non-player characters, leaving high-risk locations, or protecting another character from social pressure [13], [37]. Clear rules define what counts as a successful or unsuccessful response, and they can be informed by cognitive-behavioral models (e.g., refusal is rewarded, acceptance of a drink leads to negative in-game consequences) [56].

Meaningful choices are central for both gameplay and therapy. The player should face dilemmas that resemble real-life decisions, with multiple possible actions rather than a single correct response [51]. Feedback then closes the loop: immediate feedback (visual, auditory, social) can signal the short-term consequences of a choice, while delayed feedback can illustrate longer-term outcomes, such as deterioration or improvement in relationships, health, or daily functioning [50]. Progression mechanisms, levels, increasing difficulty, and unlocking of new scenarios allow the system to start with relatively simple situations and gradually introduce more complex social or emotional challenges. This structure is consistent with graded exposure and skills training in cognitive-behavioral approaches [38], [56].

When these elements are coherently designed, the game mechanics become a scaffold for therapeutic practice. The logic of the game enforces repetition of target behaviors under varying constraints, while the consequence structure can model both the costs of maladaptive responses and the benefits of coping strategies [47], [50], [53]. In frameworks such as Action-Centered Exposure Therapy (ACET), this alignment between mechanics and therapeutic goals is explicit. Patients must complete tasks while being exposed to cues, and successful task performance requires the use of coping strategies that are relevant to their everyday risk situations [13].

C. Experiential Learning Through Action

Experiential learning theories emphasize that knowledge and skills emerge through cycles of action, feedback, reflection, and abstraction [57]. This is the core mechanism shared by the action-centered approaches of Section VI-B; serious games instantiate it by placing the player in situations that require doing something rather than merely reading or listening. The player must interpret the context, select an action, observe its

consequences, and adjust subsequent behavior accordingly [46], [58].

In the context of alcohol-related interventions, experiential learning through action can support the development of coping strategies that are difficult to train through didactic methods alone. For instance, a game can require the player to decline drinks, redirect attention away from alcohol-related stimuli, or use specific verbal and non-verbal tactics to handle social pressure [13], [38]. Because the environment is simulated, mistakes do not carry real-world harm, which may reduce the fear of failure and encourage exploration of new responses, a factor identified as important for motivation and persistence in addiction treatment [59], [60].

Virtual reality amplifies this potential by situating the player's actions within the embodied and enactive framework of Section VI-B: instead of clicking on abstract icons, the user moves, looks around, manipulates objects, and interacts with characters [33], [34]. This situated practice can make coping strategies more concrete and memorable; whether such in-game experiences transfer to daily life is addressed in Section XI [43], [44]. Designing for experiential learning therefore requires not only interactive scenarios but also opportunities for debriefing and reflection, for example through therapist guidance or in-game prompts that encourage the user to connect virtual experiences with real-world situations [41], [42].

D. Repetition and Variation of Risk Situations

Therapeutic change in addiction often relies on repeated practice in the presence of risk cues. Exposure-based and cognitive-behavioral approaches emphasize contact with high-risk situations and the rehearsal of alternative responses [55], [61]. Serious games can support this process by structuring repetition of core tasks while varying the surrounding context. In this way, repetition may foster familiarity with coping responses and contribute to weakening maladaptive cue-response associations, whereas variation may reduce context specificity and improve the generalization of skills to novel situations [61].

In a game-based intervention, the same underlying objective, such as refusing a drink or securing an environment, can be instantiated across multiple locations (bar, home, workplace), times of day, and social configurations (strangers, friends, family, colleagues) [13], [37]. Non-player characters may adopt different attitudes, ranging from supportive to pressuring or hostile, which forces the player to adapt strategies and reflects the diversity of social dynamics encountered in everyday life [62]. Environmental factors such as noise, crowding, or the presence of salient alcohol cues can be manipulated to modulate difficulty, consistent with graded exposure principles [63].

From a design standpoint, repetition and variation must be carefully balanced. Excessive repetition without meaningful change can lead to boredom and disengagement, while too much variation without underlying structure may hinder consolidation of skills [47]. Game systems can address this by introducing progression rules (e.g., increasing the density of cues or the complexity of social interactions) and by monitoring performance to adjust challenge levels, in line with concepts

such as the flow experience and adaptive difficulty [64], [65]. Importantly, therapeutic alignment requires that variation is not merely aesthetic but systematically explores dimensions that are clinically relevant for the individual's risk situations [42], [55].

E. Engagement Without Trivialization

One of the main motivations for using serious games is to enhance engagement, particularly in populations where motivation for treatment may be fragile [46]. Reward structures, narrative elements, and playful interfaces can make therapeutic exercises more attractive and reduce drop-out, which is a recurrent challenge in addiction services [48], [60]. How such engagement is defined and interpreted as an evaluation construct is addressed in Section X-B. However, in the context of alcohol use disorder, there is a risk that gamification may trivialize the severity of the condition or send ambiguous messages about drinking [50].

Designers must therefore strike a balance between engagement and seriousness. Aesthetic choices, tone, and narrative framing should avoid glamorizing alcohol or turning risky behaviors into entertaining challenges [49]. Instead, the game can highlight the effort and value of coping, the complexity of social situations, and the emotional impact of choices on oneself and others, which connects to broader work on empathy and social cognition in AUD [66], [67]. Characters can be portrayed with nuance and dignity, reducing stigma while still making consequences visible [60].

Engagement also depends on usability and accessibility. Complex controls, confusing interfaces, or technical difficulties can quickly undermine the intended motivational benefits [47]. From an HCI standpoint, careful user-centered design, iterative testing with target users, and attention to comfort (particularly in VR) are necessary to ensure that the game remains engaging without inducing frustration, cybersickness, or emotional overload [7]. Collaboration with clinicians and people with lived experience of alcohol problems is crucial to maintain ethical and therapeutic coherence [48].

F. Limits of Gamification

While gamification and serious games offer valuable tools for structuring practice and supporting engagement, they have clear limits. Turning therapeutic tasks into game mechanics does not automatically guarantee clinical effectiveness, and there is a risk of overemphasizing surface features (scores, badges, achievements) at the expense of underlying processes [68], [69]. If rewards are poorly aligned with therapeutic goals, they may even reinforce undesirable behaviors, such as focusing on speed rather than quality of coping responses [47].

Moreover, gamified interventions may not suit all patients. Some individuals may perceive games as childish, stigmatizing, or incompatible with their self-image, particularly in adult clinical populations [46]. Others may feel uncomfortable with competitive elements or time pressure. Accessibility issues related to technology, literacy, and gaming experience can also limit uptake [50]. These factors underline the importance of personalization and of offering serious games as one option

among others rather than as a mandatory component of care [48].

From a methodological standpoint, many studies on gamified interventions in addiction rely on small samples, short follow-up periods, and self-reported outcomes [36], [49]. As discussed in Section XI, more rigorous evaluation designs are needed, including randomized controlled trials where appropriate and long-term assessments of behavior change and relapse [43], [46]. Gamification should not be seen as a substitute for therapeutic relationships, social support, or structural interventions. Instead, it can be conceptualized as a medium through which established approaches, such as cognitive-behavioral therapy, exposure, or empathy training, are operationalized in interactive and experiential formats [13], [41], [70].

VIII. EMPATHY AND SOCIAL COGNITION IN ALCOHOL USE DISORDER

In this article, empathy and social cognition are treated as *promising but provisional* therapeutic targets for Alcohol Use Disorder (AUD), rather than as empirically validated mechanisms of change. Clinical studies in AUD populations report impairments in emotion recognition, theory of mind, and affective empathy, and these difficulties have been linked to interpersonal problems and relapse risk [62], [66], [67], [71], [72]. At the same time, research in other domains shows that virtual reality can manipulate perspective-taking, embodiment, and social presence, and that serious games can represent complex interpersonal situations and moral dilemmas [20], [47], [73]–[75]. However, these technological capabilities have not yet been robustly demonstrated to improve clinical outcomes in AUD. To avoid overgeneralization, we explicitly distinguish three levels of evidence: (1) *clinical* findings on empathy-related impairments in AUD; (2) *technological* evidence that VR and games can elicit empathy-related or perspective-taking responses, mostly in non-clinical populations; and (3) *translational hypotheses* that such mechanisms *may* be useful for AUD interventions, conditional on future empirical validation.

a) Operational Definitions: Embodiment and Empathy: In this review, both *embodiment* and *empathy* are treated as design-relevant constructs that must be operationalized in terms of concrete interaction properties and measurable outcomes, rather than as broad labels. Table I summarizes the main constructs and how they are understood for the purpose of this narrative review.

As summarized in Table I, the constructs targeted by immersive and game-based interventions for AUD span both *intrapersonal* dimensions (e.g., embodiment, self-focused presence) and *interpersonal* dimensions (e.g., emotion recognition, empathic concern, social presence). In the remainder of this section, empirical studies are discussed in relation to these specific components rather than under the generic heading of “empathy” or “social cognition”, in order to reduce conceptual ambiguity and to highlight which aspects are actually addressed by existing interventions.

TABLE I
OPERATIONAL DEFINITIONS OF KEY SOCIO-EMOTIONAL AND EMBODIED CONSTRUCTS USED IN THIS REVIEW

Construct	Operational meaning in this review	Typical indicators / measures
Embodiment	Sense of having, controlling, and being located in a body or viewpoint within the virtual environment, including the experience that the virtual body or actions are “mine”.	Presence/embodiment questionnaires, body-ownership ratings, behavioral alignment (reaching, locomotion), sensorimotor contingencies.
Cognitive empathy / perspective-taking	Understanding and representing another person’s mental and emotional state, including the ability to adopt another’s viewpoint.	Perspective-taking scales, Theory of Mind tasks, narrative-based social cognition assessments.
Affective empathy / emotional resonance	Sharing or mirroring another’s affective state in response to their situation or expressions.	Self-report affect and empathy scales, physiological responses (e.g., heart rate), observed emotional reactions.
Empathic concern / compassion	Other-oriented motivation to help, comfort, or protect another person in distress.	Prosocial choice tasks, helping behavior in interactive scenarios, self-reported concern or motivation to support others.
Theory of Mind (ToM)	Inferring beliefs, intentions, and other propositional mental states in social situations.	Standard ToM tasks (e.g., false-belief, social stories), advanced emotion attribution tasks.
Emotion recognition	Correct identification and labeling of facial, vocal, or bodily emotional expressions.	Emotion recognition tests, performance-based social cognition batteries.
Social presence	Feeling that virtual agents or avatars are socially “real” and available for interaction, beyond mere graphical representation.	Social presence questionnaires, behavioral indicators of engagement with avatars (gaze patterns, proximity, turn-taking).

A. Definitions and Conceptual Boundaries

Empathy is typically defined as the capacity to understand and share another person’s emotional state, and is commonly decomposed into at least two major components. Cognitive empathy refers to the ability to infer and understand what others feel or think, including perspective-taking and the attribution of mental states. Affective empathy denotes emotional resonance with another’s experience, such as feeling concern or distress in response to another person’s suffering, and is often linked to prosocial tendencies [16], [67]. These facets are related but distinguishable, and empirical work indicates that they can be differentially affected in Alcohol Use Disorder (AUD) [62].

Empathy is closely related to, yet distinct from, several neighboring constructs. Compassion generally involves an orientation toward alleviating another’s suffering, going beyond resonance to include caring motivation and prosocial action tendencies. Sympathy commonly denotes feeling for another person (e.g., pity or concern) without necessarily requiring accurate perspective-taking or shared affect. Theory of Mind (ToM) refers to the capacity to attribute beliefs, intentions, and other mental states to oneself and others, and partially overlaps with cognitive empathy while not necessarily involving affective sharing [76]. Perspective-taking is a specific cognitive operation in which an individual deliberately adopts another’s viewpoint; it is often treated as a subcomponent of cognitive empathy and ToM rather than as a standalone construct.

Social cognition provides a broader umbrella for these phenomena. It can be defined as the set of processes involved in perceiving, interpreting, and using social information, including emotion recognition, ToM, empathy, attributional styles, and social decision-making. In the context of AUD, social cognition is relevant both for understanding interpersonal difficulties and for designing psychosocial interventions. Conceptual clarity is essential, as many studies use overlapping labels (e.g., “empathic accuracy”, “emotional perspective-taking”, “social

perception”) to refer to partially distinct processes and measures. For an HCI-oriented review, distinguishing these constructs helps avoid conflating outcomes targeted by immersive systems (e.g., empathy, emotion recognition) with broader clinical variables (e.g., relapse risk, quality of life).

B. Social Cognition in Alcohol Use Disorder

A substantial body of research suggests that AUD is associated with alterations in social cognition, although the strength and specificity of these effects vary across tasks and samples. One well-documented domain concerns the recognition of emotional facial expressions. Several studies report that individuals with AUD show reduced accuracy or biased patterns when identifying basic emotions, and that these difficulties are associated with interpersonal problems and social functioning issues [18], [77]. More recent systematic work indicates that emotional processing in AUD involves both perceptual and evaluative components, with potential links to neural circuits subserving affective evaluation and regulation [18].

Beyond emotion recognition, deficits have been observed in higher-order social cognition such as ToM and humor processing. Uekermann et al. reported that patients with alcoholism showed impairments in ToM tasks and in the comprehension of humorous material, in association with executive dysfunction, suggesting that prefrontal alterations may contribute to social cognitive difficulties [76]. These findings are broadly consistent with the hypothesis that chronic alcohol use can affect neural systems implicated in both cognitive control and socio-emotional evaluation.

Social cognition in AUD is also intertwined with relational and contextual dimensions. Difficulties in interpreting others’ intentions, reduced sensitivity to non-verbal cues, and biased attributional tendencies have been linked to interpersonal conflict, social withdrawal, and misunderstandings of others’

reactions to drinking behavior, both in clinical and non-clinical samples [16]. In non-clinical populations, higher alcohol use, especially when driven by coping motives, has been associated with lower behavioral empathy, suggesting that patterns of alcohol consumption may erode responsiveness to others' needs and distress in everyday interactions [67]. Complementary evidence from systematic reviews and meta-analyses indicates that lower empathy and poorer ToM abilities are reliably, albeit modestly, associated with heavier alcohol use and more alcohol-related problems [16], [78].

However, causal interpretations require caution. Many studies are cross-sectional, and social cognition may be influenced by a combination of premorbid traits, chronic alcohol exposure, comorbid conditions, and environmental stressors. Longitudinal and mechanistic evidence remains limited, particularly regarding the directionality between social-cognitive alterations and trajectories of alcohol use [16]. From the perspective of immersive technologies and serious games, these findings highlight that AUD is not only a disorder of consumption patterns but also a condition in which social information processing and interpersonal functioning can be affected. Interventions that explicitly engage social cognition should therefore be designed with an awareness of existing vulnerabilities (e.g., difficulties reading emotions, mistrust, stigma) and should avoid assuming intact socio-cognitive abilities in all patients.

C. Cognitive and Affective Components of Empathy

Empirical studies in AUD populations treat cognitive and affective empathy as distinct, measurable components, although the pattern of their involvement varies across studies and samples. Nachane et al. examined men with alcohol dependence and found that both cognitive and affective empathy were lower than in healthy controls, with empathic functioning higher in abstinent men, associated with progression in the motivational cycle, and negatively correlated with the number of relapses [62]. These findings carry clinical relevance: the co-occurrence of cognitive and affective empathic deficits may compound interpersonal difficulties during active drinking, while the partial remission of empathic deficits with abstinence suggests that empathy could be a malleable target in recovery-oriented interventions.

Other work has linked empathic difficulties in AUD to emotional processing anomalies and alexithymia, i.e., difficulties in identifying and describing one's own emotions [18]. When individuals struggle to access and label their internal states, both affective resonance with others and accurate interpretation of social cues may be compromised. Such profiles can contribute to interpersonal misunderstandings, reduced responsiveness to others' distress, and challenges in forming supportive relationships.

Measurement approaches reflect this multidimensionality. Self-report instruments often differentiate perspective-taking, empathic concern, and personal distress, while performance-based tasks may assess emotion recognition, ToM, or affective responsiveness to social stimuli. Meta-analytic and review work on empathy and addiction underscores that specific facets (e.g., affective empathy, empathic concern) may be more strongly

associated with substance use patterns, motivation for treatment, and social functioning than global empathy scores [79]. For design-oriented research, this implies that immersive systems should specify which empathy components they intend to engage (e.g., perspective-taking vs. empathic concern) and choose measurement tools accordingly.

D. Empathy, Alcohol-Related Behaviors, and Social Context

Empathy is embedded in a broader social context that shapes alcohol-related behaviors. On the one hand, reduced empathic capacity can exacerbate impulsive and self-focused patterns, weaken sensitivity to the impact of drinking on close others, and contribute to social isolation [16], [67]. On the other hand, social support, caring relationships, and empathic understanding from peers and professionals are repeatedly identified as protective factors in recovery trajectories [80], [81].

Social environments play a dual role in AUD. Social pressure, drinking norms, and peer influence can encourage excessive consumption and make abstinence or moderation more difficult, especially in contexts where alcohol is central to social belonging. At the same time, supportive networks can provide practical help, emotional validation, and alternative models of coping with stress without resorting to alcohol. When empathic capacities are diminished, individuals may misinterpret others' intentions or fail to recognize concern and limits set by loved ones, which can further strain relationships.

From a socio-cognitive viewpoint, it is important to consider not only how empathy affects interpersonal behavior, but also how social interactions feed back into empathic development or erosion. Chronic exposure to stigma and moralizing attitudes toward addiction can damage trust and reduce openness to others' perspectives [81]. Conversely, therapeutic approaches that emphasize empathic listening, collaborative decision-making, and respect for autonomy, such as motivational interviewing and certain forms of cognitive-behavioral therapy, aim to *leverage* empathic processes as part of change [3], [80], although specific causal pathways between empathy change and clinical outcomes in AUD remain insufficiently documented. As a result, claims of direct therapeutic effects of empathy enhancement in AUD should be made with caution and framed as hypotheses rather than established mechanisms.

For an HCI and VR perspective, these contextual considerations suggest that empathy-related design should not be isolated from the social realities of AUD. Scenarios that depict the consequences of alcohol use on others, experiences of social support or rejection, and the dynamics of social pressure are likely to resonate with the socio-emotional landscape described in the clinical literature. Yet, designers must avoid assuming that increasing empathic responses in VR will automatically translate into reduced consumption or relapse risk; as discussed in Section XI, the relationship between socio-emotional learning in virtual environments and durable behavioral change remains an open empirical question.

E. Implications for Empathy-Oriented VR Design

The empirical and theoretical work reviewed above suggests several implications for the design of empathy-oriented VR

and serious games in the context of AUD. First, given that both cognitive and affective empathy can be diminished in AUD [18], [62], VR scenarios can be structured to explicitly scaffold cognitive empathic skills (e.g., guided perspective-taking, reasoning about intentions and consequences) while *gently inviting* affective engagement through carefully crafted socio-emotional situations, so that neither component is left to implicit processing.

Second, the documented difficulties in emotion recognition, ToM, and alexithymia indicate that virtual characters should communicate their states using redundant, multimodal cues (facial expressions, body language, contextual information, and explicit dialogue) rather than relying on subtle non-verbal signals alone [76], [77]. This is particularly relevant for users who may struggle with fine-grained emotional decoding; immersive systems can *potentially* scaffold social understanding by making relevant cues more salient and by allowing repeated exposure and practice in a controlled environment.

Third, the ambivalent role of social context in AUD, as both a risk factor (through peer pressure and drinking norms) and a protective resource (through social support and empathic relationships), suggests that empathy-oriented VR design should encompass a range of social scenarios. These might include situations where the user witnesses or experiences pressure to drink; interactions in which the consequences of alcohol use on close others become salient; and episodes of supportive communication in which empathic listening and validation are modeled. By making such dynamics experientially available, VR could provide a “sandbox” for exploring alternative responses to social cues related to alcohol, although the extent to which such experiences influence real-world behavior remains an open empirical question.

Fourth, the presence of stigma and moralizing attitudes toward addiction in many real-world contexts calls for careful ethical framing [81]. Empathy-oriented VR interventions should avoid reinforcing shame or guilt and instead emphasize understanding, shared humanity, and agency. Narrative structures that position the user as a collaborator in care, rather than as a judge or passive observer, may be particularly valuable. This aligns with person-centered therapeutic approaches that prioritize respect, autonomy, and collaborative problem-solving.

Finally, the methodological literature on empathy and social cognition in addiction highlights the need for clear operationalization and measurement of targeted constructs [79]. For HCI and VR researchers, this implies that interventions should specify whether they aim to influence cognitive empathy, affective empathy, emotion recognition, ToM, or broader social functioning, and should select validated instruments accordingly. Experimental designs must distinguish between immediate experiential outcomes (e.g., perceived empathic engagement in VR, presence, social presence) and longer-term behavioral or clinical outcomes (e.g., changes in drinking behavior, relationship quality). As illustrated by recent enactive VR work in AUD [70], design-oriented studies can play a crucial role in exploring feasibility, acceptability, and experiential coherence, but claims of therapeutic effectiveness should be explicitly presented as *translational hypotheses* that require subsequent, rigorously controlled clinical research.

In addition, measurement practices in empathy-oriented VR and game-based interventions remain heterogeneous and often exploratory. Many studies rely predominantly on self-report questionnaires for empathy, presence, or social presence, with small samples and limited longitudinal follow-up, making it difficult to draw firm conclusions about durability of effects or clinical relevance. Behavioral and physiological indicators (e.g., helping choices, gaze patterns, heart-rate responses) are sometimes included but are not yet standardized across studies, and few works directly link changes in socio-emotional measures to subsequent alcohol-related outcomes such as craving, relapse, or treatment adherence. For AUD-focused interventions, these methodological constraints imply that current evidence should be interpreted primarily in terms of feasibility, acceptability, and experiential coherence, while claims about therapeutic efficacy remain, at this stage, translational hypotheses rather than established mechanisms of change.

In summary, empathy and social cognition in AUD provide both constraints and opportunities for immersive intervention design. Rather than assuming that empathy can be straightforwardly “trained” in VR with direct therapeutic impact, designers and researchers should treat empathy as a complex, multidimensional construct embedded in social and clinical realities [70], and should integrate this complexity into the conception, evaluation, and ethical framing of empathy-oriented immersive systems.

IX. IMMERSIVE TECHNOLOGIES FOR EMPATHY AND PERSPECTIVE-TAKING

Immersive technologies, and virtual reality (VR) in particular, have been increasingly explored as tools to elicit empathy, foster perspective-taking, and support social cognition [20], [73]. Rather than functioning as an automatic “empathy machine”, VR provides a set of design affordances, namely immersion, presence, embodiment, and controllable social interactions, that can be leveraged to operationalize specific components of empathy under controlled conditions [74], [82]. In the context of Alcohol Use Disorder (AUD), these affordances open promising avenues for addressing social and relational dimensions of the disorder, such as stigma, impaired perspective-taking, and difficulties in understanding the consequences of alcohol use on others [16]. However, the empirical evidence remains heterogeneous, and careful conceptual distinctions are needed to avoid overgeneralization [20], [82]. Accordingly, this section primarily maps translational opportunities and design directions rather than established AUD-specific intervention effects.

A. Immersive Perspective-Taking

A key promise of VR for empathy enhancement lies in immersive perspective-taking, that is, allowing users to experience a situation from the standpoint of another person within a simulated environment [20], [83]. Perspective-taking in VR can be implemented through different camera viewpoints (first-person or third-person), narrative framing, and interaction constraints that encourage users to adopt the goals, perceptions, or vulnerabilities of a virtual character [73], [74].

First-person perspective is often assumed to be more effective for empathy because it tends to increase bodily self-location and identification with the avatar, especially when combined with visuo-motor synchrony and strong embodiment cues [84]. Empirical studies report that first-person, embodied perspective-taking experiences can increase target-specific cognitive empathy and prosocial tendencies toward the individual or group whose perspective is adopted [83], [85]. Meta-analytic and review work nonetheless indicates that these effects are modest and context-dependent: VR perspective-taking reliably enhances empathy and perspective-taking toward related targets, but generalization to unrelated contexts or broader attitudes is limited or mixed [19], [74].

Third-person perspective can support reflective observation of a social situation and may reduce emotional overload, which can be beneficial in sensitive clinical contexts such as AUD [20], [73]. Some studies suggest that third-person or bystander viewpoints may be more suitable when the goal is to foster analytic understanding of social dynamics rather than intense emotional engagement [74], [82]. Overall, existing findings indicate that viewpoint modulates the balance between emotional and cognitive components of empathy, but no single configuration systematically outperforms the others across contexts [73], [74].

B. Embodiment and Virtual Body Transformation

Embodiment refers to the extent to which users experience a virtual body as their own, typically operationalized through components such as body ownership, self-location, and agency [32], [86]. In VR, embodied experiences are often produced through visuo-motor synchrony and avatar control, which can induce the illusion of inhabiting a different body, including bodies that differ in age, gender, ethnicity, or health status [84].

Experimental work shows that avatar embodiment can modulate self-perception and social attitudes. For instance, embodying an outgroup member has been associated with short-term changes in implicit bias and intergroup attitudes, although findings are mixed and sometimes indicate adverse effects when the simulated experience is highly negative or distressing [82], [87], [88]. Systematic reviews suggest that, under certain conditions, embodied perspective-taking can enhance cognitive empathy by immersing individuals in another person's viewpoint, while emotional responses depend strongly on scenario content and user characteristics [20], [73].

In AUD-oriented applications, embodiment could theoretically be used to let individuals inhabit the body of a significant other (e.g., a family member) or a future self affected by the long-term consequences of alcohol use [87]. Such designs remain largely speculative and require rigorous evaluation, as they may induce strong emotional reactions, moral distress, or defensive responses that could counteract therapeutic goals [74], [82].

C. Virtual Characters and Social Interaction

Virtual characters and social agents are central to many empathy-oriented VR experiences. They allow the design of controlled social encounters with verbally and nonverbally

expressive others, whose behaviors can be scripted, parameterized, and adapted to the user's actions [23], [89], [90]. Research on social presence, defined as the sense of "being with" other sentient entities in mediated environments, shows that believable social behaviors, contingent responsiveness, and appropriate nonverbal cues (gaze, posture, facial expressions) contribute to perceiving virtual characters as socially real and deserving of moral consideration [23], [89], [91].

In empathy-focused VR, virtual characters may represent outgroup members, victims of harm, or people affected by users' actions. Studies report that interacting with such characters in immersive environments can increase perceived social presence and, in some cases, empathic concern, especially when narratives highlight vulnerability and shared human needs [20], [74]. However, mixed results and occasional backfire effects (e.g., increased defensiveness or bias) underline that the design of virtual social interaction must be carefully tuned and ethically informed [82], [87].

For AUD, believable virtual characters could theoretically be used to display the social consequences of alcohol-related behaviors (e.g., family distress, workplace conflict), but current empirical work on such designs is scarce. Most VR studies in AUD focus on exposure to alcohol cues and craving modulation, rather than on complex social interaction or empathy [9].

D. Experiencing the Consequences of Alcohol Use on Others

One frequently discussed, but still underexplored, possibility is to use immersive perspective-taking to let individuals experience the consequences of their alcohol use on others, such as family members, colleagues, or strangers [74], [82]. Conceptually, this aligns with cognitive-behavioral and social learning approaches that emphasize awareness of interpersonal impacts and responsibility [3], [16].

Empirically, however, there is currently limited evidence that VR scenarios explicitly depicting the relational harms of alcohol use produce durable changes in empathy or behavior in clinical AUD populations. Existing VR studies in substance use disorders mostly focus on cue exposure, craving induction, or attentional bias, rather than on structured perspective-taking about others [1], [9]. Moreover, work on VR-mediated empathy in other domains suggests that strong emotional simulations can lead to guilt, shame, or defensive reactions that may hinder therapeutic progress if not carefully framed [74], [82].

Therefore, designs aiming to make individuals "feel what others feel" as a result of alcohol use should be treated as experimental hypotheses rather than established clinical tools. They require careful piloting, ethical oversight, and integration into broader therapeutic frameworks that include psychoeducation, motivational interviewing, and supportive debriefing [1].

E. Empathy-Oriented Scenario Design

Scenario design plays a pivotal role in whether immersive experiences support empathy in a constructive way. Reviews of VR empathy interventions emphasize that narrative structure, goal framing, and choice architecture strongly influence outcomes [20], [73]. Scenarios that clearly articulate objectives

(e.g., understanding another person's constraints), provide meaningful choices and consequences, and avoid overly didactic or moralizing tones tend to foster more genuine perspective-taking and self-reflection [74], [82].

Perspective (first-person vs. third-person), temporal framing (present vs. future consequences), and the degree of agency granted to users all modulate the balance between emotional engagement and analytic distance [83], [85]. Providing structured debriefing after the experience is widely recommended to help participants articulate their reactions, distinguish between emotional contagion and empathic understanding, and connect virtual insights to real-world contexts [20].

In AUD-related designs, scenario simplification constitutes a significant risk. Alcohol use and its social consequences are complex, contextual, and embedded in broader socioeconomic and psychological factors [1]. Overly simplified narratives that portray alcohol users as one-dimensional perpetrators of harm or others as passive victims can reinforce stigma rather than empathy [74], [82]. Empathy-oriented scenario design should therefore strive to represent ambivalence, structural constraints, and multiple perspectives, including those of the person with AUD, their relatives, and professionals [16], [80].

F. Measuring Empathy in Immersive Systems

Measurement of empathy in VR systems is methodologically challenging. A recent systematic review of studies using head-mounted displays (HMDs) identified over one hundred experiments that attempted to quantify empathy changes following immersive experiences [20]. The predominant tools are self-report psychological scales, such as the Interpersonal Reactivity Index (IRI) and the Questionnaire of Cognitive and Affective Empathy (QCAE), combined in some cases with qualitative interviews or behavioral proxies [20], [73].

Meta-analytic results indicate that, under specified conditions, VR can improve empathy, but effects differ across components and time scales [20], [74]. Emotional empathy often increases temporarily after the VR experience and tends to return toward baseline over time, whereas cognitive empathy may show more sustained improvements, especially in designs that emphasize narrative coherence and embodiment [20], [83]. Importantly, VR has not consistently outperformed less immersive interventions such as reading narratives or guided imagination, particularly regarding emotional empathy [74], [82].

Methodological heterogeneity remains a major limitation. Studies vary in their operationalization of empathy (trait vs. state, cognitive vs. affective), timing of measurement (immediate vs. delayed), and inclusion of behavioral indicators (e.g., prosocial choices, donations, helping behavior) [20], [73]. Social desirability and demand characteristics also pose challenges, as participants may infer the intended outcome of an "empathy" intervention and adjust their self-reports accordingly [20], [74], [82]. For AUD, these issues are compounded by clinical factors such as shame, stigma, and ambivalence about change [16], [80].

G. Ethical Risks and Design Precautions

Ethical considerations are central to empathy-oriented immersive designs, particularly when targeting vulnerable populations such as individuals with AUD [1], [80]. VR simulations that depict suffering, discrimination, or interpersonal harm can induce strong emotional reactions, including distress, guilt, or shame [82], [87]. While some level of discomfort may be acceptable within therapeutic frameworks, excessive or poorly supported distress risks retraumatization, disengagement, or defensive rationalization [74], [82].

The literature on VR and empathy highlights several ethical risks: emotional manipulation, moralizing narratives, reinforcement of stereotypes, and lack of informed consent regarding the intensity of the experience [74], [82]. Design precautions therefore include clear pre-exposure briefing, the possibility to interrupt the session at any time, the presence of trained professionals when working with clinical populations, and systematic debriefing to process emotions and reframe the experience [1].

In addition, empathy-focused simulations can inadvertently shift responsibility entirely onto individuals, obscuring structural determinants of health and social outcomes [1], [74], [82]. For AUD, this may reinforce self-blame and stigma if the focus is solely on the harm caused to others without acknowledging addiction as a chronic, multifactorial condition that requires supportive care [16], [80]. Ethical design must therefore balance awareness of consequences with recognition of vulnerabilities, resilience, and the possibility of change.

H. Evidence, Limitations, and Open Questions

The current evidence on immersive technologies for empathy and perspective-taking is promising yet inconclusive. Reviews and meta-analyses converge on the view that VR can, under certain conditions, enhance specific components of empathy and influence attitudes toward particular targets [20], [73], [83]. However, several limitations and open questions remain.

First, the distinction between presence, perspective-taking, and empathy is often blurred. High presence (the feeling of "being there" in the virtual environment) does not automatically entail accurate perspective-taking or genuine empathic concern [32], [82]. Conversely, empathic insight may arise from relatively low-tech interventions, such as reading narratives or engaging in guided imagery. Comparative studies indicate that VR is not systematically more effective than non-immersive empathy interventions, particularly regarding emotional empathy [74], [82].

Second, most documented effects are short-term and target-specific. Increases in empathy or prosocial attitudes immediately after a VR experience do not necessarily translate into long-term behavioral change or generalization to real-world situations [20], [85]; as discussed in Section XI, whether immersive empathy interventions can influence relapse risk, treatment adherence, or interpersonal functioning over meaningful time scales remains largely unexplored [1], [9].

Third, measurement heterogeneity complicates synthesis. Studies use different empathy scales, social cognition tasks, and behavioral proxies, often without clear distinction between

cognitive, affective, and behavioral dimensions [20], [73]. This heterogeneity raises concerns about construct validity and makes meta-analytic integration difficult.

Finally, the notion of VR as an inherent “empathy machine” is not supported by current evidence. Technology provides powerful means to create controlled, engaging, and embodied experiences, but empathy emerges from a complex interplay among scenario design, user characteristics, clinical context, and broader social meanings [74], [82], [92]. In AUD research and practice, immersive empathy-oriented interventions should therefore be framed as experimental tools whose benefits, mechanisms, and risks must be empirically demonstrated rather than assumed [1], [80].

X. HCI EVALUATION OF IMMERSIVE INTERVENTIONS

Immersive technologies for AUD are not only clinical tools but full socio-technical systems. Their evaluation therefore requires HCI-oriented criteria such as usability, accessibility, user experience, presence, embodiment, safety, and acceptability, in addition to clinical outcomes [47]. In this section, we review how these dimensions are typically assessed and how they shape the feasibility of immersive interventions in practice.

A. Usability and Accessibility

From an HCI perspective, immersive interventions must first be usable and accessible for their intended users, including patients with AUD and the professionals who support them [47]. Usability broadly covers effectiveness, efficiency, and satisfaction in performing the required tasks, whereas accessibility concerns whether diverse users can realistically access and operate the system given their physical, cognitive, and socio-economic constraints.

In VR-based health applications, usability challenges often arise from complex controller layouts, 3D menu navigation, and the cognitive load associated with learning new interaction paradigms [93]. These issues can be exacerbated in AUD populations, where comorbidities such as cognitive impairments, anxiety, or depressive symptoms may reduce tolerance for demanding interfaces and lengthy onboarding procedures [1]. Interfaces that rely heavily on text, multi-step menus, or precise motor control may therefore hinder effective use and adherence [47].

Accessibility adds further constraints. Not all patients have reliable access to head-mounted displays or the space required for room-scale VR, and some may experience visual or motor limitations that affect their ability to use standard controllers [1]. Inclusive design strategies, such as seated modes, simplified control schemes, adjustable visual settings, and multimodal feedback, are important to reduce these barriers [93]. In addition, differences in prior experience with games or VR may strongly influence how quickly users can engage with the system [47].

HCI evaluations typically employ task-based usability testing, error analysis, and established questionnaires such as the System Usability Scale or short custom instruments adapted to the clinical context [47]. Observational methods and think-aloud protocols can reveal misunderstandings, interface breakdowns,

and points of friction that may not appear in quantitative metrics [47]. However, many immersive AUD studies report only clinical or psychological outcomes and provide limited information about basic usability and accessibility [9]. This lack of systematic reporting makes it difficult to compare interventions and assess their feasibility for real-world deployment [47].

B. User Experience and Engagement

User experience (UX) and engagement are central evaluation dimensions for serious games and immersive health technologies [47], [94]. While usability focuses on task performance, UX addresses the subjective quality of the experience, including affective responses, perceived meaning, and overall satisfaction [47]. Engagement refers to the intensity and temporal dynamics of users’ involvement with the system, encompassing both behavioral and experiential aspects [47]. A note of caution is in order: several of the HCI and UX studies cited in this section were conducted in adjacent addiction populations, such as gambling disorder; their application to AUD therefore constitutes an extrapolation that should be evaluated with care.

Immersive AUD interventions typically aim to balance hedonic and eudaimonic components of UX. Hedonic qualities include enjoyment, curiosity, and the intrinsic appeal of interaction and exploration [47]. Eudaimonic qualities relate to reflection, insight, and perceived personal growth, such as increased awareness of triggers, consequences, or coping options [94]. Gamification mechanisms, feedback, progression systems, challenges, narrative framing, are often used to increase short-term engagement, but they may also shape how users interpret the seriousness and credibility of the therapeutic content [47].

Engagement can be measured through log data (session frequency and duration, number of completed modules, interaction density), self-report scales on enjoyment, interest, or perceived usefulness, and behavioral indicators such as voluntary re-use and drop-out patterns [47]. Qualitative interviews and open-ended questionnaires are useful to capture nuanced experiences, including ambivalence, boredom, or emotional overload that may not be visible in aggregate engagement metrics [94].

Importantly, high engagement does not automatically imply therapeutic benefit [47], [94]. A highly engaging exposure scenario could, for example, intensify craving without sufficiently supporting coping strategies, or could encourage repeated use while reinforcing maladaptive patterns [1]. Conversely, an intervention that is perceived as emotionally demanding or confrontational may show moderate engagement but still support meaningful reflection and change when used in a structured clinical context [94]. HCI evaluation must therefore distinguish between engagement as a design outcome and clinical effectiveness as a health outcome, and avoid inferring the latter from the former without appropriate evidence [47].

C. Presence, Plausibility, and Social Presence

Presence, plausibility, and social presence are key constructs in the evaluation of immersive systems [23], [91]. Presence typically refers to the subjective feeling of “being there” in the

virtual environment, while plausibility denotes the perceived credibility of events and interactions, that is, the sense that what happens in the virtual world is genuinely occurring to the user despite knowing it is simulated [32]. Social presence concerns the perception of other entities, avatars, virtual agents, or remote users, as socially real and responsive [89], [90].

In AUD-related VR, presence and plausibility are often considered prerequisites for effective simulated exposure [23], [95]. A strong sense of presence can intensify cue reactivity and emotional involvement, making virtual bars, supermarkets, or social gatherings feel closer to real-life situations [29]. Plausible social interactions and environmental details can increase perceived relevance and transfer value: if the user experiences the scenario as realistic and personally meaningful, coping responses practiced in VR may be more easily recalled in daily life [95], [96]. However, very high presence and plausibility can also amplify distress, craving, or shame, and thus require careful calibration and clinical oversight [1].

Social presence plays a particularly important role when immersive interventions target empathy, social cognition, or interpersonal skills [23], [89]. For example, scenarios involving family members, peers, or health professionals rely on the user perceiving virtual characters as authentic social partners rather than mere scripted objects [23]. The richness of nonverbal behavior, responsiveness, and affective signaling in avatars can substantially influence perceived social presence, and thereby modulate emotional engagement, perspective-taking, and the practice of refusal or negotiation strategies [23], [97].

HCI evaluations commonly rely on standardized presence questionnaires and social presence scales, complemented by behavioral observations (e.g., user reactions to virtual events, postural responses, spontaneous communication) [89], [91]. Yet, many studies report presence scores primarily as indicators of technical success or experiential quality, without explicitly examining how presence, plausibility, and social presence relate to specific therapeutic mechanisms or outcomes [23]. A more systematic integration of these constructs into study designs, such as comparing different levels of environmental realism or social responsiveness, would help clarify their functional role in AUD interventions.

D. Embodiment and Agency

Embodiment, as defined in Section VI-B, is evaluated here in terms of the extent to which users experience a virtual body as their own, including body ownership, self-location, and agency [32]. Agency can be considered both at the sensorimotor level, feeling in control of the avatar's movements, and at the task level, perceiving that one's actions shape the unfolding of events and outcomes in the scenario [98].

In immersive interventions, strong embodiment can make simulated situations feel more personally relevant and impactful, as users experience themselves as acting within the scene rather than merely observing it from a distance [32]. For AUD-oriented scenarios, this may be particularly important when training coping strategies or refusal skills: the sense that "I am the one making this choice and experiencing its consequences" can support perceived self-efficacy and agency in relation to alcohol-related contexts [98], [99].

At the same time, agency must be carefully managed. Overly constrained or scripted interaction can undermine users' sense of control and reduce the opportunity to practice adaptive behaviors [98]. Conversely, fully open-ended scenarios may place heavy cognitive and emotional demands on patients, especially if they have limited prior experience with games or VR [47]. Balancing guided structure with meaningful action opportunities is therefore a central design challenge [98].

HCI evaluations of embodiment and agency typically use self-report questionnaires on body ownership and perceived control, combined with behavioral measures such as reaction to virtual threats, accuracy and timing of actions, or patterns of exploration and interaction [32]. Qualitative feedback can reveal subtle discrepancies between intended and perceived agency, such as feeling "pushed" toward certain choices or experiencing the avatar as behaving autonomously [98]. Systematic reporting of embodiment and agency metrics is still limited in the AUD VR literature, which makes it difficult to assess how interaction design choices influence users' experience of control and responsibility [23].

E. Cybersickness, Comfort, and Safety

Cybersickness, physical comfort, and psychological safety are critical evaluation dimensions for immersive interventions, especially in clinical populations [93]. Cybersickness encompasses symptoms such as nausea, dizziness, oculomotor strain, and disorientation, often attributed to conflicts between visual and vestibular signals, high latency, or aggressive locomotion schemes [93]. Physical comfort involves ergonomic factors including headset fit, weight, thermal load, and required postures or movements [93].

For patients with AUD, who may present additional health vulnerabilities and comorbid conditions, tolerance to VR may be lower than in young, healthy samples often used in general VR studies [1]. Experiences that are physically or visually demanding can quickly lead to discomfort or early termination, thus compromising adherence and limiting the feasibility of the intervention [93], [100]. Careful selection of locomotion techniques, frame rates, and interaction styles is therefore essential, and seating or low-intensity configurations are often preferable [93].

Psychological safety is equally important. Immersive exposure to alcohol-related situations can elicit intense craving, anxiety, guilt, or shame, particularly when scenarios depict social conflict, family distress, or relapse consequences [1], [4]. Without appropriate safeguards, these experiences may overwhelm users or reinforce negative self-views [1]. Design strategies such as gradual exposure, adjustable difficulty or intensity, clear exit options, and structured debriefing can help maintain safety while still enabling meaningful emotional engagement [1], [47].

HCI evaluations should include standardized cybersickness questionnaires, brief comfort ratings, and explicit monitoring of distress signals during and after sessions [93], [95]. In addition, protocols must specify stopping rules and support mechanisms in case of adverse reactions, in line with broader recommendations that digital interventions for substance use

disorders ensure informed consent, safety, confidentiality, and appropriate clinical support [1]. Although many VR studies in mental health acknowledge cybersickness and distress as potential issues, detailed reporting of safety-related metrics and procedures remains uneven, although severity and prevalence of cybersickness have been characterized in psychiatric VR contexts [93], [100]. For AUD, systematic attention to comfort and safety is a prerequisite for responsible experimental and clinical use [1], [80].

F. Acceptance by Patients and Professionals

Acceptance and perceived usefulness by both patients and professionals strongly influence whether immersive interventions move beyond pilot studies into routine practice [101]. From a patient perspective, acceptance depends on factors such as perceived relevance to personal goals, trust in the technology and its developers, perceived respect and non-stigmatization, and comfort with the idea of using a game-like or VR-based tool for a serious condition [1].

Stigma and concerns about judgment can be particularly salient in AUD, and are known to limit help-seeking and access to treatment for substance use disorders, making confidentiality and clear data governance central to the design of any digital intervention [1]. Patients may worry that using a digital tool will be seen as a sign of weakness or lack of willpower, or may fear that their data could be misused or disclosed [1]. Clarity about the role of the immersive intervention within a broader care plan is also essential to patient trust and acceptance [1], [80].

Clinicians and other professionals face their own acceptance challenges [101]. They must consider how VR fits into existing workflows, what training and technical support are required, how sessions are scheduled and supervised, and whether there is sufficient evidence to justify adoption [101]. Concerns about equipment costs, maintenance, and institutional support can also shape attitudes toward immersive interventions [101]. Some professionals may be enthusiastic about innovative tools, while others may be cautious or resistant due to time pressures and perceived complexity [101].

HCI evaluation of acceptance typically involves qualitative interviews, focus groups, and questionnaires addressing perceived usefulness, ease of integration, willingness to recommend, and anticipated barriers [47]. Co-design approaches can further enhance acceptance by involving patients and professionals in the early stages of design, thereby aligning the system with actual needs and constraints [47]. In the current literature on immersive AUD interventions, systematic assessment of acceptance is still limited, and many studies focus primarily on short experimental exposures rather than long-term integration into practice [23], [101].

G. Distinguishing Feasibility from Clinical Effectiveness

A crucial methodological distinction in the evaluation of immersive interventions is between feasibility, broadly encompassing usability, accessibility, UX, presence, embodiment, safety, and acceptance, and clinical effectiveness, which refers to measurable improvements in health outcomes such as

reduced alcohol consumption, decreased craving, improved abstinence rates, or enhanced quality of life [41], [43].

Feasibility-oriented HCI studies typically ask whether the system can be deployed and used as intended: Do patients understand and tolerate the interactions? Is cybersickness acceptable? Are the sessions manageable within clinical workflows? Do users experience sufficient presence and agency for the scenarios to make sense? Does the system respect safety and ethical constraints [47]? These studies often rely on small samples, descriptive statistics, and mixed methods to identify strengths, weaknesses, and design refinements [47].

Clinical effectiveness studies, in contrast, aim to test whether the intervention produces reliable and clinically meaningful changes in predefined outcomes, usually through controlled designs such as randomized trials or longitudinal cohorts [41], [43]. Demonstrating effectiveness requires adequate sample sizes, appropriate control conditions, validated measures of AUD severity and craving, and careful handling of confounders such as concurrent treatments and life events [41], [43].

In the current literature on immersive AUD interventions, feasibility and clinical effectiveness are sometimes conflated [41], [43]. For example, high presence scores, positive user feedback, or short-term changes in self-report measures may be interpreted as evidence of therapeutic potential, even when study designs and sample sizes are insufficient to support robust causal claims [41], [43]. This conflation can lead to overoptimistic narratives and hinder the development of a clear evidence base.

Distinguishing feasibility from clinical effectiveness is therefore essential. HCI-focused evaluations should explicitly frame their objectives as assessing usability, experience, and safety, and avoid extrapolating to long-term clinical benefits [47]. Conversely, clinical trials should build on prior feasibility work and incorporate HCI measures to interpret outcome patterns and identify mechanisms of action [41], [43]. For AUD, where relapse dynamics and contextual factors are complex, a staged evaluation strategy, from design and feasibility studies to well-controlled effectiveness trials, is particularly important to ensure scientific rigor and ethical responsibility [1], [9].

XI. TRANSFER TO REAL-WORLD SITUATIONS

Immersive interventions for AUD ultimately aim not only to improve in-game performance or short-term self-report measures, but to support durable changes in real-world behavior, coping, and social functioning. The notion of *transfer* is therefore central: it concerns whether skills, attitudes, and insights acquired in virtual environments generalize beyond the specific training context, remain stable over time, and manifest in everyday situations that are only partially similar to those experienced in VR [96].

A. Defining Transfer

In the broader learning sciences and educational psychology, transfer is typically defined as the application of knowledge or skills learned in one context to a different context [96]. A classic distinction is drawn between *near transfer* and *far transfer* [96]. Near transfer refers to the application of learning

to situations that closely resemble the training environment in terms of stimuli, tasks, or required responses, whereas far transfer concerns the use of acquired competences in novel, more complex, or structurally different contexts [96].

In the case of immersive interventions for AUD, near transfer might involve applying coping strategies rehearsed in a virtual bar to a similar real-world bar with comparable social cues and alcohol availability. Far transfer, by contrast, would entail using these strategies in different settings, such as family gatherings, work-related events, or solitary drinking situations, where triggers, social expectations, and emotional dynamics can differ substantially [96].

Transfer is also closely related to *generalization*, i.e., the extent to which learned responses become applicable across a range of stimuli and contexts, rather than being tied to specific virtual scenarios [96]. For AUD, this generalization is particularly important given the diversity of real-world high-risk situations and the role of contextual factors in relapse [8], [21]. Finally, the *maintenance* of transfer effects over time is crucial: short-lived improvements that fade after a few weeks are unlikely to produce meaningful changes in health outcomes [41], [43].

B. Transfer of Coping Skills

Many immersive interventions for AUD explicitly aim to train coping strategies, such as attentional redirection, stimulus control, refusal skills, or self-regulation techniques in the presence of alcohol cues [41], [43]. In VR-based cue exposure or action-centered approaches, patients are encouraged to rehearse alternative responses in high-risk scenarios, with the expectation that these responses will later be deployed in everyday life [13], [41].

From an HCI and learning perspective, several design choices influence the likelihood of such transfer. First, coping strategies must be *explicitly represented* in the interaction design, for instance through clear goals, meaningful choices, and immediate feedback about the consequences of different actions [47]. Second, repeated practice across varied scenarios is required to avoid overfitting to a single context and to strengthen generalization [96]. Third, the link between in-game strategies and real-world applications needs to be made transparent to the user, either through narrative framing, guidance by a therapist, or structured debriefing.

Empirically, however, evidence for robust transfer of coping skills from immersive environments to long-term drinking behavior remains limited. Existing studies in AUD typically rely on short-term experimental exposures, small samples, and self-report measures, making it difficult to determine whether trained strategies are used consistently in everyday situations and whether they contribute to reduced relapse rates [5], [12]. Current findings therefore support the feasibility and acceptability of coping-oriented immersive interventions, but warrant caution when extrapolating to durable real-world effects [96].

C. Transfer of Social and Empathic Learning

Beyond individual coping, immersive technologies can also target social and empathic dimensions of AUD, such as

perspective-taking, recognition of others' needs, and communication in supportive or high-risk interactions [102], [103]. For example, some interventions place the user in situations involving family members, peers, or colleagues, where relational dynamics and social cues are central to the scenario [74], [82].

From a theoretical standpoint, VR is well suited to support social and empathic learning, because it can manipulate perspective (first-person vs. third-person), simulate non-verbal behavior, and create a strong sense of presence in shared or social environments [95]. Experiences that encourage users to adopt another person's viewpoint, respond to subtle emotional cues, or engage in supportive dialogue may foster changes in attitudes and interpersonal behavior [102].

However, the empirical basis for transfer of social and empathic learning in AUD-focused immersive interventions is still sparse. Most available studies either target anxiety disorders or general prosocial attitudes, or they focus on immediate changes in empathy scores rather than long-term interpersonal outcomes [5], [16]. In the specific context of AUD, where social cognition can be impaired and stigma plays a major role in help-seeking and recovery, these approaches are promising but require systematic evaluation before strong claims about real-world transfer can be made [103], [104].

D. Contextual Variation and Ecological Validity

Transfer is closely linked to *ecological validity*, i.e., the degree to which virtual scenarios capture the complexity and variability of real-life situations. If immersive interventions only present highly stylized or simplified environments, learned responses may fail to generalize to the messy, ambiguous contexts in which drinking decisions actually occur [96].

To support transfer, designers can vary contextual parameters such as location (bar, home, workplace), time of day, social composition (friends, strangers, family), emotional tone, and availability of alternative activities [47]. Such variation exposes the user to a broader range of triggers and response options, reducing context-specificity and encouraging flexible adaptation [96]. At the same time, ecological validity must be balanced with usability and safety: overly complex or emotionally intense scenarios can increase cybersickness, distress, or cognitive overload, undermining engagement and learning [93].

Current immersive AUD interventions often focus on a limited set of prototypical risk situations, such as bars or parties, which facilitates control and standardization but may restrict transfer to other contexts where drinking occurs, including solitary or work-related situations [8], [21]. Expanding the repertoire of scenarios and allowing personalization based on the patient's own history could enhance ecological validity and, potentially, transfer [96].

E. Debriefing and Reflective Integration

Transfer is not only a matter of repeated exposure, but also of *reflective integration*. After an immersive session, users need to make sense of what they experienced, connect it to their own life, and plan concrete actions for future real-world situations [47]. Therapeutic debriefing, guided reflection, or

structured self-report tools can help bridge the gap between virtual practice and everyday behavior [96].

Several design elements can support this process:

- prompts that encourage users to articulate what strategies they used and why;
- discussion of moments of difficulty or near-relapse in the virtual environment;
- explicit mapping between in-game decisions and analogous real-world choices;
- collaborative planning of how to apply learned strategies in upcoming high-risk situations [47].

The existing VR/AUD literature indicates that such integrative components are still relatively rare. Many studies emphasize the immersive exposure itself but devote less attention to post-session reflection and transfer planning [96]. From an HCI perspective, incorporating debriefing and reflective tools into the design of immersive interventions, rather than treating them as optional add-ons, may be critical to support durable change [47].

F. Longitudinal and Behavioral Evaluation

Finally, robust assessment of transfer requires longitudinal and behavioral evaluation strategies that go beyond immediate post-session measures. For AUD, clinically meaningful transfer should manifest as changes in drinking patterns, craving dynamics, coping responses, and social functioning over extended periods, ideally captured through objective or semi-objective indicators [41], [43]. Yet, many VR and serious-game interventions for AUD are tested in short-term experimental designs, with limited follow-up and reliance on self-report questionnaires [5], [30].

From an HCI and clinical research perspective, future studies will need to integrate:

- longer follow-up windows to assess maintenance of effects and relapse patterns;
- behavioral measures such as actual drinking behavior, ecological momentary assessment of coping responses, or performance on standardized tasks;
- multi-informant data, including clinician ratings and, where appropriate, reports from family or peers [41], [43];
- ethical and privacy safeguards for the sensitive behavioral, gaze, vocal, and physiological data that immersive systems can collect, together with rigorous clinical evaluation of adaptive or conversational interaction components.

Such designs are more demanding in terms of resources and ethics, but they are essential to move from promising feasibility results to reliable evidence about transfer and clinical effectiveness [96]. More broadly, these requirements are consistent with public health priorities for AUD, which emphasize long-term reductions in harmful use, improved treatment coverage, and better social functioning rather than short-lived changes in proximal indicators [1]. Aligning immersive intervention studies with these outcome dimensions would help clarify their potential contribution to real-world AUD care and health system strengthening [1].

XII. CRITICAL SYNTHESIS AND RESEARCH GAPS

The function of this section is diagnostic: it summarizes what the reviewed evidence does and does not support, and it identifies the research gaps that follow from this assessment. The interpretation of these findings, the design and research agenda they motivate, and the final positioning of the field are treated in the Discussion (Section XIII), while the constraints of this review itself are stated in Section XIII-E.

The overall picture is consistent across the bodies of work reviewed: immersive and interactive technologies for Alcohol Use Disorder (AUD) occupy an intermediate position between experimental tools, psychoeducational media, and potential adjuncts to treatment. The literature suggests that these systems can reliably elicit craving, support coping rehearsal, or foster reflection on alcohol-related situations under controlled conditions, but that their conceptual framing, interaction design, methodological rigor, and translational maturity remain uneven [8], [21].

A. Conceptual Ambiguities and Misalignments

The literature suggests that several foundational constructs are employed in heterogeneous ways across studies, including embodiment, agency, presence, empathy, and social cognition [16], [62], [70], [71], [83], [92]. In clinical research on AUD, empathy and social cognition typically refer to specific capacities such as emotion recognition, theory of mind, or affective empathy. In contrast, HCI and VR studies often use the term “empathy” more broadly to describe experiences that are emotionally engaging, prosocial, or morally reflective, without clearly specifying which component is targeted or how it is operationalized [74], [87].

Presence, embodiment, and agency present a similar pattern. Some reports treat these constructs as distinct dimensions with different implications for craving, coping, and interaction, whereas others subsume them under a single notion of “immersion” or “realism” [20], [47]. This conceptual ambiguity complicates the comparison of studies and makes it difficult to identify which aspects of experience are most relevant to AUD outcomes.

A further misalignment concerns the way different intervention logics are grouped under the umbrella of “VR-based treatment”. Cue exposure, coping skills training, perspective-taking, and empathy-oriented social interaction emerge as distinct families of intervention with different theoretical assumptions and therapeutic goals [8], [105]. Based on this observation, the field would benefit from work that specifies, for each study, (i) which mechanism of change is being targeted, (ii) which outcomes are expected, and (iii) which features of the immersive system are intended to support that mechanism; how such specifications could be made and tested is taken up in the future-research agenda of the Discussion (Section XIII-D).

B. Design Limitations in Scenario Richness and Social Interaction

From a design perspective, the literature indicates that many current systems focus on relatively constrained environments

and scripted interactions. Alcohol cues are often presented in bar, store, or home settings with limited variation, and non-player characters frequently display restricted behavioral repertoires [4], [7], [47]. Such designs can be effective for eliciting craving or practicing basic coping responses, but they may provide only a narrow representation of the complex social and contextual challenges encountered in everyday life with AUD.

Social interaction appears as a particularly underdeveloped dimension. Several studies demonstrate the feasibility of including virtual humans and social pressure scenarios, yet the responsiveness, emotional nuance, and relational continuity of these agents remain limited [74], [87]. This constrains the range of possible interpersonal experiences, such as negotiating refusal, dealing with stigma, or repairing strained relationships.

The design agenda that follows from these limitations is developed in the Discussion (Section XIII-C).

Ethical and emotional-safety considerations also appear unevenly integrated into interaction design. Some studies explicitly anticipate distress, shame, or guilt and describe procedures for briefing, monitoring, and debriefing, whereas others offer limited detail on how emotional risks are managed [1]. This unevenness is a gap in the current evidence base rather than an established design rule; the Discussion (Section XIII-C) develops the corresponding design and evaluation implications.

C. Methodological Weaknesses and Limited Longitudinal Evidence

Methodologically, the literature shows substantial heterogeneity in samples, protocols, control conditions, and outcome measures [8], [9], [21]. Sample sizes are often modest, and studies vary widely in terms of inclusion criteria, clinical status, and treatment context. Exposure duration, interaction patterns, and assessment instruments differ across projects, which limits the comparability of results and the accumulation of robust evidence.

In addition, many evaluations remain short-term and laboratory-based. User experience dimensions such as usability, cybersickness, presence, embodiment, social presence, and emotional safety are not consistently reported, and follow-up data on craving, consumption, or coping in everyday life are relatively scarce [20], [47], [105]. The literature therefore provides only limited support for strong claims about sustained behavioral change or real-world transfer.

A cautious synthesis of this evidence base is therefore that immersive environments can reproduce clinically relevant situations, trigger craving, and serve as platforms for rehearsing coping strategies under controlled conditions, whereas durable changes in drinking behavior or social functioning remain an open empirical question to be addressed through longitudinal designs, ecological assessment, and multi-site studies [9], [21].

D. Translational Barriers and Implementation Challenges

Finally, translational and implementation issues are only partially addressed in the existing literature. Relatively few studies are situated within clearly defined care pathways or specify how immersive systems are intended to interact

with existing psychosocial interventions such as motivational interviewing, cognitive-behavioral therapy, or mutual-help groups [3], [10], [34]. Questions of clinician training, workflow integration, equipment cost, maintenance, accessibility, and organizational readiness are mentioned as constraints but rarely examined systematically [1], [80].

This has direct implications for how the current evidence base should be interpreted. On the one hand, feasibility and acceptability studies suggest that many patients and practitioners are willing to engage with immersive systems and perceive them as potentially useful [8], [21]. On the other hand, the lack of implementation-focused research warrants caution: promising prototypes cannot be assumed to be scalable or sustainable without explicit attention to adoption, equity, and long-term maintenance.

The translational gap identified here is one of the four that structure this section, and it grounds the implementation-science and translational priorities set out in the Discussion (Section XIII-D).

XIII. DISCUSSION

A. From Exposure to Situated Action

Across the reviewed literature, immersive systems for AUD predominantly use virtual reality as a medium for realistic cue presentation and craving induction [8], [11], [22]. Virtual bars, parties, or domestic environments are designed to reproduce typical drinking contexts and to trigger subjective and physiological responses under controlled conditions [21], [34]. This emphasis on exposure aligns with established relapse-prevention and extinction-based models, in which repeated confrontation with conditioned stimuli in the absence of consumption is expected to weaken cue-response associations [3], [10].

At the same time, the review suggests that many immersive interventions remain limited to *passive* exposure or to narrowly constrained response options, such as observing, reporting craving, or making a binary drinking choice [8], [105]. From a cognitive-behavioral perspective, however, exposure is most effective when embedded in broader learning processes, including attentional control, situation appraisal, coping strategy acquisition, and behavioral rehearsal in high-risk contexts [3], [10]. This points to a conceptual shift from exposure *as presentation* toward exposure *as situated action*, in which users are invited to enact protective behaviors, negotiate social pressure, and practice adaptive problem-solving.

Some serious-game approaches and training systems already move in this direction by embedding alcohol-related challenges within interactive tasks, decision points, and feedback structures [12], [37]. However, these designs remain relatively rare in AUD-focused VR and are often evaluated primarily in terms of feasibility, usability, or short-term craving modulation rather than changes in coping skills or everyday behavior [8], [105]. The literature therefore supports viewing cue exposure as a starting point for *embodied and situated* practice rather than as a complete therapeutic interaction in itself [8], [105].

B. Role of Empathy in Socially Situated Interventions

Empathy and social cognition emerge in the literature as important but under-specified dimensions of AUD and its treatment. The association between empathy-related deficits and clinical variables (severity, interpersonal difficulties, and relapse risk) was already established as the clinical anchor in Section VIII [62], [76], [77], [79]; here we focus on its implications for intervention design rather than on re-documenting the association itself. At the same time, psychosocial and motivational interventions often rely on increasing awareness of the interpersonal consequences of alcohol use, strengthening therapeutic alliance, and mobilizing social support, which implicitly engage empathic processes [3], [80].

In immersive research beyond AUD, VR has been explored as a potential “empathy machine”, with studies examining whether embodied perspective-taking, virtual body ownership, and narrative immersion can influence attitudes, bias, or moral judgment [85], [87], [92]. Systematic reviews and conceptual analyses, however, caution against assuming direct or generalized empathic effects: outcomes depend strongly on scenario content, social context, user characteristics, and measurement choices [20], [92]. Within AUD-specific VR and serious-game work, empathy is rarely defined explicitly or treated as a primary mechanism of change [8]; as highlighted in Section XII-A, constructs such as empathy, presence, embodiment, and agency are often used inconsistently across studies, which complicates the comparison of outcomes and mechanisms.

Taken together, the reviewed literature suggests that empathy should be understood as a *supportive* mechanism within socially situated interventions rather than as an automatic product of immersion. Immersive systems may plausibly contribute to:

- making interpersonal consequences more salient through social scenarios and virtual characters;
- supporting perspective-taking on the experiences of relatives, peers, or other affected parties;
- encouraging reflection on stigma, support, and relational repair in everyday contexts [81], [85], [87].

However, the literature reviewed here does not provide sufficient evidence to claim robust, clinically validated empathy-enhancing effects of VR in AUD. Empathy-oriented designs should therefore remain experimental and exploratory, with explicit hypotheses, multidimensional measurement, and ethical safeguards rather than being presented as established therapeutic tools [1], [20], [92].

C. Implications for Immersive-System Design

From an HCI perspective, several implications for the design of immersive systems for AUD can be derived from the reviewed work.

First, *interaction design* should move beyond static or minimally interactive cue exposure toward richer forms of embodied, goal-directed activity. This includes tasks in which users must navigate complex environments, manage attention, and engage in meaningful actions such as refusing drinks, seeking support, or changing context in ways that align with coping and relapse-prevention strategies [3], [12], [65]. Such designs should be informed by theories of motivation and

engagement, including intrinsic motivation, flow, and self-efficacy, to sustain user involvement without reproducing problematic reward structures [106]–[108].

Second, *social and empathetic dimensions* can be incorporated through carefully designed non-player characters, dialogues, and social cues that represent realistic relationships and social pressures while avoiding stereotypes or moralizing narratives [85], [109], [110]. Designers should consider social presence, plausibility, and narrative coherence as important conditions for users to perceive virtual agents as socially meaningful partners, without over-claiming empathic change [23], [89], [90].

Third, *evaluation-oriented design* is crucial. Given the methodological gaps identified in the literature, immersive systems should be developed with built-in support for logging interaction traces, integrating validated questionnaires, and enabling controlled manipulation of conditions such as interactivity, social complexity, or perspective-taking [8], [34]. This would facilitate systematic studies and align design choices with clinically meaningful outcomes and measurement strategies [12], [21].

Fourth, the uneven integration of emotional-safety and usability concerns documented in Section XII-B implies that comfort, cybersickness, accessibility, and informed-consent procedures should be treated as core design and evaluation targets for AUD populations, rather than as external procedural requirements [1], [47], [80].

D. Priorities for Future Research

The priorities below are the constructive counterpart of the gaps identified in Section XII; each names the specific gap it is meant to close, together with the methods that would close it. The design implications of Section XIII-C and the empirical program sketched here should therefore be read as conceptual proposals awaiting empirical verification, not as established practice.

First, there is a need for *more rigorous clinical trials* and longitudinal studies evaluating immersive interventions for AUD, including randomized controlled designs, adequate sample sizes, and follow-up periods sufficient to assess relapse and maintenance outcomes [8], [21], as discussed in Section XI. This priority addresses the methodological and longitudinal gaps documented in Section XII-C. Such studies should compare immersive interventions not only with passive controls but also with established psychosocial treatments, such as CBT or digital programs, in order to clarify added value [10].

Second, *mechanism-focused research* is required to disentangle the specific contributions of immersion, embodied interaction, social scenarios, and empathic framing. Factorial designs and experimental manipulations can help determine whether and how particular design features, such as viewpoint, agency, or narrative framing, influence craving, coping responses, and social cognition [34], [85], [87]. This would move the field from generic claims about “VR effects” toward more precise and testable models of change, addressing the conceptual and mechanism-level ambiguities documented in Section XII-A.

Third, future work should invest in *measurement development and standardization*. Building on existing reviews of presence,

empathy, and social cognition measures, researchers can develop and validate frameworks that distinguish cognitive, affective, and behavioral components and that are suitable for repeated use in immersive contexts [20], [89], [91]. This would improve comparability across studies and support more robust synthetic analyses, directly addressing the measurement heterogeneity documented in Section XII-C.

Fourth, *diversity and inclusiveness* should be addressed more explicitly. Most current studies focus on relatively narrow populations, such as treatment seekers, specific age groups, or single cultural contexts, which limits generalization [5], [8]. Future research could examine how immersive interventions function across different genders, age groups, cultural backgrounds, and comorbidity profiles, and how designs can be adapted accordingly [1]. This priority addresses the population and sample limitations documented in Section XII-C.

Finally, *translational research* bridging laboratory prototypes and clinical practice is essential. This includes work on implementation models, integration into care pathways, training for professionals, cost-effectiveness analysis, and organizational factors that influence adoption [1], [21], [80]. Without such efforts, promising immersive interventions risk remaining at the proof-of-concept stage; this priority operationalizes the translational gaps identified in Section XII-D.

E. Limitations of This Narrative Review

The limitations below concern *this review* as a methodological object; they are distinct from the gaps in the field's own evidence documented in Section XII.

This article adopts a narrative rather than systematic review methodology. Although the search strategy was structured and multi-disciplinary, it does not aim to be exhaustive with respect to all immersive or game-based interventions for AUD and related conditions [5], [12]. Selection and synthesis therefore reflect the author's focus on HCI, immersive technologies, and empathy-oriented design, which may underrepresent other relevant strands of addiction research.

Second, the review draws on heterogeneous studies with varying designs, sample sizes, measurement tools, and clinical populations. This is a property of the source corpus that the review inherits and reports; it additionally precludes any quantitative synthesis on the review's own side, with a residual risk that stronger or more recent studies are emphasized over older or less accessible work [8], [20]. Where possible, claims have been restricted to what is directly supported by the cited literature, and conflicting findings have been acknowledged.

Third, the discussion of empathy and social cognition relies partly on studies conducted outside AUD, including work on bias reduction, conflict resolution, and general emotion recognition [76], [77], [85], [87]. While these sources are conceptually informative, their findings cannot be directly extrapolated to AUD populations without dedicated empirical validation.

Finally, although the literature screening and the initial thematic coding were conducted by a single reviewer, with the co-authors critically reviewing the framework and the manuscript, this review may still be subject to interpretive bias

in how theories and findings are connected. Future systematic reviews, meta-analyses, and interdisciplinary position papers could complement this work by providing more formalized inclusion criteria, quality assessments, and consensus-building processes [12], [23].

XIV. CONCLUSION

This narrative review has examined how immersive, embodied, and empathy-oriented technologies are currently used and conceptualized in relation to Alcohol Use Disorder. It has brought together literature on VR cue exposure, serious games, coping-oriented interventions, and social cognition to clarify the state of the art from an HCI perspective.

Three broad tendencies emerge. First, immersive systems for AUD have so far primarily focused on realistic cue exposure and craving assessment, with growing but still limited integration of structured, action-oriented coping practice [8], [11], [22]. Second, empathy and social cognition are increasingly recognized as relevant dimensions for understanding AUD and designing psychosocial support, but are rarely targeted explicitly or measured systematically in immersive interventions [20], [62], [76], [77]. Third, methodological and translational gaps related to sample sizes, comparison conditions, longitudinal follow-up, and clinical integration continue to limit conclusions about the long-term effectiveness and real-world impact of these technologies [1], [8], [21].

On this basis, immersive, embodied, and empathy-oriented systems should currently be understood as *promising experimental tools* and potential adjuncts to established psychosocial interventions rather than as standalone or clinically validated treatments [3], [10], [34]. Their distinctive contribution lies in the possibility of combining controlled exposure, situated action, and socially meaningful interaction within ecologically rich yet safe environments [34], [85], [87], a potential that can only be realized through the conceptual, design, measurement, and translational program set out in the Discussion. For HCI and immersive technology research, AUD offers a challenging but highly relevant domain in which to examine how exposure, situated action, social presence, and empathic framing can be orchestrated to support behavior change, with the understanding that any clinical claims must be empirically demonstrated and continuously re-evaluated.

AUTHOR CONTRIBUTIONS

F. Ehret: conceptualization, methodology, literature search and screening, writing: original draft. Y. Francillette: supervision, writing: review and editing. B.-A. J. Menelas: supervision, writing: review and editing.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

ETHICS APPROVAL

Not applicable: this is a narrative review of published literature, and no new research involving human or animal subjects was conducted.

DATA AVAILABILITY

The full reference list and the search details are provided in the Appendices of this manuscript.

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APPENDIX A

SEARCH DETAILS

This appendix details the information sources and the keyword families used in the review, organized around the four thematic clusters of Section II.

TABLE II: Keyword families per thematic cluster, in English and French.

Thematic cluster	English keywords (example search terms)	French keywords (example search terms)
Immersive cue exposure and craving induction	virtual reality, immersive environment, alcohol use disorder, alcohol dependence, substance use disorder, craving, cue exposure, exposure therapy	réalité virtuelle, environnement immersif, trouble d'usage de l'alcool, addiction, craving, exposition aux indices
Serious games and experiential learning	serious game, game-based, gamification, experiential learning, motivation, flow	jeu sérieux, jeux sérieux, ludification, apprentissage expérientiel, motivation
Embodiment, agency, and presence	embodiment, spatial presence, immersion, cybersickness, avatar	incarnation, présence spatiale, immersion, cybersickness
Empathy and social cognition	empathy, theory of mind, social cognition, perspective taking, social presence	empathie, théorie de l'esprit, cognition sociale, prise de perspective

Databases and roles. PubMed (clinical and addiction-medicine literature); IEEE Xplore and ACM Digital Library (human-computer interaction, virtual-reality engineering, human factors); Scopus and Web of Science (cross-disciplinary coverage of serious games, gamification, and social cognition); Google Scholar (citation snowballing); HAL and the Cairn index (French-language academic literature). Institutional sources (WHO, NIAAA, national health agencies) were consulted for epidemiological context and clinical guidance.

Example Boolean chains.

- *PubMed:* ("Virtual Reality"[tiab] OR "immersive virtual environment"[tiab]) AND ("Alcohol Use Disorder"[MeSH] OR "alcohol"[tiab]) AND ("craving"[tiab] OR "cue exposure"[tiab] OR "exposure therapy"[tiab])
- *IEEE Xplore:* "virtual reality" AND ("serious game" OR "alcohol") AND ("craving" OR "exposure" OR "presence")
- *Cairn/HAL:* "réalité virtuelle" AND ("addictions" OR "alcool") AND ("exposition" OR "jeu sérieux" OR "empathie")

Searches were conducted intermittently between 2021 and 2026; the corpus was frozen in June 2026 and re-checked in August 2026. Records were screened in English and French, and the retained corpus is predominantly in English.

APPENDIX B

THEMATIC SYNTHESIS OF THE LITERATURE

TABLE III: Thematic synthesis of literature on immersive, embodied, and empathy-oriented technologies relevant to Alcohol Use Disorder (AUD).

Theme	Typical interventions and examples	Main outcomes reported	Recurring methodological limitations	Implications for AUD research and design
Immersive cue exposure and craving induction	VR environments that present alcohol-related cues and high-risk situations (bars, parties, domestic settings) to assess or modulate craving and cue reactivity. Examples include VR cue-exposure protocols and scoping/systematic reviews on VR in AUD and substance use disorders (e.g., [8], [11], [21], [22], [30], [111]).	Immediate changes in subjective craving, physiological responses (heart rate, skin conductance), and self-reported anxiety or urge to drink. Some studies report high presence and acceptability, and exploratory evidence that VR can evoke stronger craving than traditional imagery or pictures (e.g., [5], [11]).	Small samples (often $n < 60$), heterogeneous inclusion criteria, and short follow-up durations. Frequent use of non-standardized craving and presence measures, limited reporting of long-term outcomes (relapse, consumption), and scarce randomized controlled trials [8]. Potential selection bias towards treatment-seeking or convenience samples.	VR cue exposure appears promising as an assessment and experimental tool to study craving in ecologically rich contexts, and as an adjunct to cognitive-behavioral or relapse-prevention approaches [8], [11]. Future work should integrate standardized craving and presence measures, larger and more diverse samples, and longer-term outcomes to clarify whether VR-based exposure meaningfully improves relapse prevention beyond conventional methods [5], [21].
Serious games and experiential learning for addiction and mental health	Game-based and gamified interventions designed to promote psychoeducation, self-monitoring, coping skills, or behavior change in mental health and addiction. Examples include serious games in healthcare and well-being [12], [112], gamified learning and flow-based designs [113], and conceptual work on serious games for learning [75], [114].	Reported outcomes include increased engagement, motivation, and self-reported learning, as well as improvements in knowledge, attitudes, or self-efficacy in various health domains. Some pilot studies suggest potential benefits for adherence and short-term symptom reduction, though evidence specific to AUD remains limited and mostly indirect [12].	Predominance of pilot or feasibility studies with small samples, limited control groups, and short-term evaluation. Outcome measures often focus on engagement, satisfaction, or knowledge rather than clinically robust endpoints (e.g., consumption, relapse, functional impairment). Variable quality in usability and UX reporting, and scarce explicit links to established therapeutic models [12].	Serious games offer design strategies for experiential learning, interactive coping practice, and engagement in AUD interventions. For AUD, game mechanics should be explicitly aligned with evidence-based psychosocial treatments (e.g., CBT, relapse prevention [3], [10]) and evaluated not only on engagement but also on clinically meaningful outcomes. Flow, feedback, and challenge-skill balance can be leveraged to support sustained practice of coping strategies, provided that ethical and safety constraints are respected.
Embodiment, agency, and action-centered coping practice	Immersive systems that emphasize bodily engagement, sensorimotor contingencies, and user agency in virtual environments (e.g., avatar embodiment, first-person perspective, interactive manipulation of alcohol cues or protective behaviors). Conceptual and empirical work on embodiment, the Proteus effect, and behavior change through self-representation [84], [86], [88], as well as general VR-based action and presence studies.	Outcomes include changes in sense of body ownership and spatial presence, altered self-perception and behavior (e.g., embodiment-related bias reduction), and improved task performance in action-based VR tasks. Some evidence suggests that embodied interaction can strengthen engagement and learning, but direct clinical effects on AUD-related outcomes are not yet established.	Many studies are conducted with non-clinical or non-addicted populations, making clinical transfer uncertain. Embodiment and agency are often measured with diverse, non-standardized questionnaires or ad hoc scales. Experimental setups frequently isolate specific factors (e.g., avatar appearance) but do not connect them to long-term health or behavior-change outcomes relevant to AUD.	Embodied and action-centered interaction offers conceptual tools to reframe exposure as active coping rehearsal rather than passive cue presentation. For AUD, interventions could emphasize enacting protective behaviors (refusal skills, alternative activities, leaving risky contexts) and negotiating social pressure in embodied, first-person scenarios. Standardized measures of embodiment, agency, and presence should be incorporated to link design choices to psychological mechanisms and potential therapeutic effects [8], [20].

Table III (continued)

Theme	Typical interventions and examples	Main outcomes reported	Recurring methodological limitations	Implications for AUD research and design
Empathy and social cognition in immersive environments	VR and serious games used to manipulate perspective-taking, social presence, and empathic engagement (e.g., embodying another person, role-playing moral dilemmas, or simulating interpersonal situations). Examples include VR empathy and bias-reduction work [85], [87], [88], a systematic review of empathy measurement in HMD-based VR [20], and serious-game approaches to interpersonal and moral scenarios [73], [74].	Reported outcomes include changes in self-reported empathy, perspective-taking, or social attitudes; modulation of implicit or explicit bias; and increased emotional engagement with simulated characters. These effects are mostly demonstrated in general or specific non-AUD populations (e.g., intergroup bias, conflict, education), and focus on proximal psychological measures rather than clinical endpoints.	Empathy constructs are operationalized and measured in diverse ways, with limited standardization and varying psychometric quality [20]. Most studies lack long-term follow-up and do not assess downstream behavioral or clinical changes. For AUD, direct intervention studies targeting empathy or social cognition with immersive technologies remain scarce, and evidence is largely extrapolated from adjacent domains [62], [71], [72].	In AUD, empathy and social cognition difficulties are associated with interpersonal problems and relapse risk [62], [66], [71], [72], but immersive empathy-oriented interventions are still at the hypothesis stage. VR and serious games can plausibly be used to represent social pressure, conflict, and support, and to train perspective-taking or emotion recognition; however, their clinical utility for AUD must be tested with dedicated trials. Future work should bridge clinical findings on empathy-related impairments with robust, standardized VR-based measurements and carefully designed, ethically sound interventions.