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Applications of virtual reality in individuals with alcohol misuse: A systematic review

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HIGHLIGHTS

- We review the literature on the applications of virtual reality in alcohol misuse.
- Virtual reality may enhance the effectiveness of cue-exposure techniques.
- Virtual Reality shows promise as an assessment and treatment tool.

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ABSTRACT

Background: Alcohol use and misuse have been intensively studied, due to their negative consequences in the general population. Evidence-based literature emphasizes that alcohol craving plays a crucial role in the development and maintenance of alcohol-drinking patterns. Many individuals develop Alcohol Use Disorders (AUD); significantly, after treatment many also experience relapses, in which alcohol craving has been repeatedly implicated. Cue-exposure therapy (CET) has been widely used in the treatment of alcohol misuse, but the results are inconsistent. Virtual reality (VR) can add effectiveness to cue-exposure techniques by providing multiple variables and inputs that enable personalized alcohol use assessment and treatment. The aim of this review was to examine the applications of virtual reality in individuals who misuse alcohol.

Method: We conducted an exhaustive literature search of the *Web of Science*, *Scopus*, *Embase*, *Google Scholar*, and *PsycInfo* databases, using as search items terms such as "alcohol" and its derivates, and virtual reality.

Results: We identified 13 studies on alcohol craving that implemented virtual reality as an assessment or treatment tool.

Conclusions: The studies that incorporate VR present clear limitations. First, no clinical trials were conducted to explore the efficacy of the VR as a treatment tool; nor were there any studies of the generalization of craving responses in the real world, or of the long-term effects of VR treatment. Despite these limitations, the studies included showed consistent results as regards eliciting and reducing alcohol craving. We suggest that VR shows promise as a tool for the assessment and treatment of craving among individuals with alcohol misuse. Further studies implementing VR in the field of alcohol consumption are now required.

1. Introduction

Craving is of great importance in the development and maintenance of alcohol-drinking behaviors (Ramirez et al., 2015). In alcohol use disorder (AUD), craving is heavily involved in drinking patterns, the severity of dependence, the maintenance of abstinence, and the risk of relapse (American Psychiatric Association, 2013; Wapp, Burren, Znoj, & Moggi, 2013). Alcohol craving is understood as a pathological appetite, a strong urge to drink alcohol, which induces neuro-psycho-physiological, emotional, behavioral, and cognitive changes in individuals with AUD (Addolorato, Leggio, Abenavoli, & Gasbarrini, 2001).

Long-term alcohol-drinking patterns determine automatic cognitive and emotional processing schema in individuals with AUD and promote compulsive drinking (Koob, 2013). Heavy drinking episodes alter the reward pathways through overstimulation of dopaminergic neurotransmission, a critical mechanism for eliciting hedonic and positive experiences. This reward mechanism strengthens alcohol drinking patterns, causing hypersensitivity to alcohol-related stimuli (Gardner, 2011; Robinson & Berridge, 1993). This chain of events leads to intense alcohol craving, relapse, and associated harmful behaviors even after many years of abstinence (Robinson & Berridge, 2008).

The treatment methods in alcohol misuse and AUD require a

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multidisciplinary approach, including pharmacological, behavioral, and psycho-social interventions. However, despite complex treatment options, many individuals diagnosed with AUD experience several relapses after interventions and a decreased quality of life because of the chronic nature of these disorders (Litten et al., 2015). Therefore, there is an urgent need to conduct more research to expand assessment and treatment approaches. Virtual reality (VR) has recently attracted attention because of its potential utility for individuals with AUD. However, only a limited amount of research has been conducted to date regarding the effectiveness of VR-based approaches in extinguishing alcohol craving and thus preventing relapses. Nevertheless, several studies suggest that VR is a promising tool for a psychological approach to AUD treatment (Bordnick et al., 2008; Choi & Lee, 2015; Son et al., 2015).

1.1. Virtual reality cue-exposure therapy for AUD

Previous studies have emphasized that alcohol craving should be targeted in reduction of alcohol consumption and in AUD treatment (for example, see Zironi, Burattini, Aicardi, & Janak, 2006). Consistent with this assumption, cue-exposure therapy (CET) attempts to elicit both subjective and physiological craving in a controlled setting, with the goal of extinguishing alcohol urges. This cue-exposure paradigm is based on classical conditioning processes (Conklin & Tiffany, 2002; Weerts, Goodwin, Kaminski, & Hienz, 2006). From a classical conditioning perspective (Pavlov, 1927), alcohol-related cues elicit conditioned responses such as alcohol craving even when no alcohol stimuli are present. Hence, empirical research suggests that alcohol-related contexts and cues are of major importance in the development and maintenance of AUD (Bottlender & Soyka, 2004).

CET methods involve in vivo, imaginary techniques or simulated exposure to alcoholic beverages by presenting auditory, visual, or photographic cues (Monti et al., 2001). Nevertheless, in a meta-analysis, Conklin and Tiffany (2002) found that CET had only modest effectiveness with inconsistent results. The authors observed that in most cases, CET was conducted in a secure, safe room with only one cue presented at a time. However, alcohol addiction is a more complex condition and typically involves the interaction and processing of multiple variables at once. Thus, craving reduction is highly context-dependent, and cue presentation in a clinical setting can reasonably be expected to interfere with generalization of newly learned responses (Lee, Kwon, Choi, & Yang, 2007; Stasiewicz, Brandon, & Bradizza, 2007). Over the last decade, CET has evolved through the development of more exhaustive treatment approaches that may benefit from VR (Saladin, Brady, Graap, & Rothbaum, 2006).

VR technology simulates and enriches real-life situations by presenting a diverse range of stimuli to create a fully immersive experience. Multiple sensory inputs (auditory, olfactory, visual, and tactile) facilitate ecological validity and provide a better alternative to classical cue-exposure methods. Lee et al. (2007) suggested that VR technology adds effectiveness to CET because of its capacity to induce greater subjective and physiological craving, which in turn prompts the generalization of treatment effects to real world, daily life activities. VR-based assessment and treatment studies have provided benefits in many psychopathologies, particularly in anxiety disorders (Maples-Keller, Bunnell, Kim, & Rothbaum, 2017; Meyerbröker & Emmelkamp, 2010), post-traumatic stress disorder (Rothbaum et al., 2014) and fear of flying (Maples-Keller et al., 2017), as well as in eating disorders (Ferrer García & Gutiérrez Maldonado, 2012), pain management (Malloy & Milling, 2010), and drug addiction (Hone-Blanchet, Wensing, & Fecteau, 2014). In AUDs, VR has been used as: a) an assessment tool (to elicit craving); and b) a VR (exposure) therapy tool (to reduce craving), variously termed VR exposure [VRE], VR therapy [VRT], or VR exposure therapy [VRET]. VRETs have achieved good results for long-term effectiveness in other disorders: for example, a 12-month follow-up study of VRET in patients with fear of flying showed long-lasting benefits (Rothbaum, Hodges, Anderson, Price, & Smith, 2002). Another study indicated that the beneficial effects of VRET on fear of flying persisted over a 3-year follow-up period (Wiederhold & Wiederhold, 2003).

The aim of this review is to provide an insightful synthesis of published studies on the applications of VR as an assessment or treatment tool in individuals with alcohol misuse. Particular emphasis is placed on the value of VR in alcohol craving.

2. Method

We conducted an exhaustive literature search of the *Web of Science*, *Scopus*, *Embase*, *Google Scholar*, and *PsycInfo* databases. The following terms were entered to find the most relevant studies: “virtual reality”, “alcohol”, “drink”, “alcohol use”, “alcohol use disorder”, “alcoholism”, “alcohol dependence”, “alcohol addiction”, and “alcohol abuse”.

The inclusion criteria were: (a) studies containing empirical data on the application of VR in individuals with unhealthy alcohol use, (b) studies published since 1990 (when VR was first used in psychology), and (c) studies reported in English. The initial search yielded 107 articles. After a careful review of their abstracts and titles, 92 articles were excluded because they concerned different psychopathologies (e.g., fetal alcohol syndrome), drugs other than alcohol (e.g., tobacco, cocaine, heroin), or had aims that were incompatible with the purpose of the current review (e.g., alcohol-induced effects on driving). Therefore, 15 relevant studies were selected for further assessment. Of these, two were written in Korean, and were therefore excluded from this review.

3. Results

A total of 13 studies met the inclusion criteria. These studies are reported in Table 1. All studies implemented VR as an assessment or treatment tool.

3.1. Objectives of the studies

The very first study to explore the effectiveness of VRET in individuals with AUD was conducted by Kwon et al. (2006). This study aimed to demonstrate that VRET for AUDs could decrease alcohol craving. Six studies were centered on VR as an assessment tool in exploring alcohol cravings (Bordnick et al., 2008; Cho et al., 2008; Choi & Lee, 2015; Kim & Lee, 2015; Lee et al., 2008; Ryan et al., 2010). Two studies (Gatti et al., 2008; Spagnoli et al., 2014) used a similar research protocol to demonstrate the effectiveness of VR as a clinical assessment tool exploring social, personality, and behavioral features of patients with AUD. Five studies used VR as a VRET instrument in the treatment of AUD (Hyun et al., 2013; Kwon et al., 2006; Lee et al., 2007; Lee et al., 2009; Son et al., 2015).

3.2. Samples

A total number of 361 individuals participated in the 13 studies, with an age range of between 18 and 50 years old. Of these, 180 participants were diagnosed with AUD, 16 participants were members of Alcoholics Anonymous, 15 were college students with binge drinking habits, 38 were heavy social drinkers, another 38 participants were light drinkers, and 74 were healthy individuals with no history of AUD.

3.3. Instruments

As shown in Table 1, all studies involved some form of questionnaire assessment (e.g. Alcohol Urge Questionnaire, Obsessive-Compulsive Drinking Scale, Alcohol Use Disorder Identification Test, or Beck Depression Inventory). Several studies (Bordnick et al., 2008; Cho et al., 2008; Hyun et al., 2013; Lee et al., 2008, 2009; Ryan et al., 2010; Son et al., 2015) also reported using a *visual analog scale* (VAS) to assess

Table 1
Summary of studies centered on the applications of virtual reality in individuals with alcohol misuse.

Study (by date)	Aims	Sample (age ± standard deviation)	Instruments (questionnaires)	VR environments	VR hardware	Procedure	Results
Kwon, Choi, Roh, Yang, and Lee (2006)	To reduce craving	*N* = 8 Individuals from AA Age 50.5 ± 14 yr	PACS AUQ OCDS	A Japanese-style pub A Western bar	Beam projector with 2.4 × 1.8 m screen Surround speakers	Participants attended 8 sessions (twice/week) consisting of: Introduction (5 min), VR navigation (VR scenes), interview (reporting thoughts and feelings), and a self-report questionnaire.	The questionnaire scores showed no significant differences before and after treatment. However, AUQ scores gradually decreased between the first and last session.
Lee et al. (2007)	To reduce craving and prevent relapse	*N* = 8 Individuals from AA, abstinent for > 3 months. Age 50.5 ± 14 yr	PACS AUQ OCDS	A Japanese-style pub A Western bar	Beam projector with a 2.4 × 1.8 m screen Surround speakers	Participants attended 8 sessions (1 session for habituation to VR, 6 VR-CET sessions based on alcohol cue-exposure, and 1 session focused on relapse prevention).	The AUQ results gradually decreased after 8 VR sessions (15.75 ± 10.91 to 11.50 ± 5.76).
Gatti et al. (2008)	To use VR to assess patients with AUD (their social, personality, and behavioral features)	*N* = 16 Individuals with AUD Age 18–50 yr Divided into experimental (*n* = 8, VR protocol) and control (*n* = 8, SCID) groups.	SCID EPI MAC2-A GSE	Four: park, apartment, office, and restaurant/pub.	N/A	Participants were submitted to: 1) park, to habituate them to the VR environment; 2) an apartment, to explore drinking habits; 3) an office, to explore emotional management skills during a job interview; and 4) a restaurant/pub, to explore social pressure on drinking behaviors.	The VR group reported greater motivation to change compared with the SCID group. The therapist obtained more behavioral and attitude data in less time from the VR group than from the SCID group. The authors suggest that the VR protocol could be used as an evaluation tool for patients with AUD.
Cho et al. (2008)	To elicit craving under social pressure	*N* = 10 Individuals with no history of alcohol-related disorders. Age 23.4 ± 2.4 yr	ADS IDS-42 Head gaze angle between the	Two with alcohol cues: Barbecue restaurant and	Environments containing (360°)	Four environments (2 × 2): With and without	A higher craving score was obtained in situations with alcohol than without alcohol (p = 0.021). Greater subjective craving was induced in situations with social pressure (with an avatar) than in situations without that pressure (p = 0.001).

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Table 1 (*continued*)

Study (by date)	Aims	Sample (age ± standard deviation)	Instruments (questionnaires)	VR environments	VR hardware	Procedure	Results
	An avatar was used		participant direction and direction of the avatar/alcohol VAS (0−100)	a bar. Two without alcohol cues: Office and street.	panoramic pictures.	avatar; with and without alcohol). Eight VR tasks were performed randomly, with small pauses between tasks to assess craving. Head gaze angle was recorded while participants were exposed to VR situations.	The angle was smaller between the direction of head gaze and the avatar compared to the direction of head gaze and the direction of alcohol ($p = 0.001$). Thus, social pressure (avatar) induced more alcohol craving than the alcohol cue itself.
Bordnick et al. (2008)	To elicit subjective craving and assess VR cue reactivity to alcohol	$N = 40$ Non-treatment seeking participants with AUD Age 39.5 ± 10.1 yr	AAS PQ VAS (0–100)	Four neutral cues (aquarium scenes). Four alcohol cues: *Hotel bar*, *kitchen*, *argument* (negative social situation), and *party*.	1. HMD and tracker (VFX-3D, Interactive Imagining Systems, Rochester, NY); 2. The Scent Palette™ (Envirodine Studios, Inc. Canton, GA); 3. Wireless game pad (P3000, Saitek, Torrence, CA).	Order of presentation was: Neutral room 1, bar, kitchen, argument, party, and neutral room 2 (with corresponding smells of different types of alcohol).	Subjective alcohol craving significantly increased when individuals were exposed to alcohol-related VR cues compared to neutral VR cues ($F_{(4, 146)} = 71.31$, $p = 0.001$). However, *lower craving* ratings were found for the argument environment. Participants rated VR environments as being *real world environments*.
Lee et al. (2008)	To assess craving (to explore the effects of social pressure and alcohol cues on triggering craving). To assess coping skills training.	$N = 28$ divided into two groups: Patients with AUD ($n = 14$; age 39.6 ± 6.0 yr) Control (healthy) group ($n = 14$; age 36.8 ± 7.4 yr)	ADS OCDS AASE VAS (0–100)	Two: a virtual street (environment without alcohol cues) and a virtual pub (environment containing alcohol cues).	HMD, tracker, speakers.	Four VR blocks (2 × 2 alcohol and social pressure): a) no alcohol cues and no social pressure, b) no alcohol cues but with social pressure, c) alcohol cues but no social pressure, and d) both alcohol cues and social pressure. The VR environments were randomly assigned.	*Virtual pub*: 1) Craving was strongly triggered in the *patient group*; 2) social pressure did not significantly affect the level of craving for patients ($t_{(13)} = 0.03$); 3) craving was elicited by social pressure in the *control group*. *Virtual street*: 4) Social pressure significantly induced alcohol cravings in both groups (control group: $t_{(13)} = -3.565$, $p = 0.003$; patient group: $t_{(13)} = -2.664$, $p = 0.019$). *Independent of social pressure, alcohol cues induce significant craving in individuals with AUD and interfere with the ability to build coping skills against social pressure.*
Lee et al. (2009)	To decrease craving.	$N = 53$ Three groups:	EEG monitoring before and after	Three: 5 min *relaxation*,	Two projectors for	*nVRTP* group: 10 general	The *VRTP* showed a greater decrease in craving after the 10 VR therapy sessions compared with the *nVRTP* group after the 10 general CBT treatment sessions ($F = 8.73$, $p = 0.01$).

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Table 1 (*continued*)

Study (by date)	Aims	Sample (age ± standard deviation)	Instruments (questionnaires)	VR environments	VR hardware	Procedure	Results
	To explore changes in alpha EEG activity in the frontal brain areas.	*VRTP* (n = 20; age 38.6 ± 5.9 yr) *nVRTP* (n = 18; age 39.1 ± 5.8 yr) *Control group* (healthy participants; n = 15, age 38.6 ± 4.6 yr).	VRT VAS (0−10)	10 min *High-risk situation* (containing alcohol cues) and 10 min *aversive environment* (vomiting scene).	stereoscopic display	treatment sessions twice per week (CBT and education). *VRTP* group: VRT was delivered for 10 weeks, twice per week, with 30 min exposure. *Procedure*: EEG monitoring for 5 min, and each participant then exposed to relaxation, high-risk, and aversive situations.	EEG alpha power increased after the tenth session of *VRTP* (z = 3.80, p = 0.01). This brain activity was interpreted as a decrease in alcohol craving. *This study showed that VRT intervention was more effective in reducing alcohol craving than cognitive-behavioral therapy among patients with AUD.*
Ryan, Kreiner, Chapman, and Stark-Wroblewski (2010)	Craving elicitation	N = 23 College students divided into 2 groups: *Binge drinkers* (n = 15; age 21.3 ± 0.8 yr) *Non-binge drinkers* (n = 8; age 28.0 ± 10.61 yr)	Pre-Post VR assessment: self-reported ratings on a Likert scale (0–10) for: Alcohol craving, attention to the sight of alcohol stimuli, attention to the smell of alcohol, and thoughts about drinking.	Five: 5 min *neutral room* (picture of underwater scenes) and four *alcohol rooms* (kitchen, bar, argument, party).	1. HMD; handheld controller; 2. Earphones; 3. The Scent Palette™ (Envirodine Studios, Inc. Canton, GA).	VR session started with exposure to a neutral environment, followed by exposure to 4 VR alcohol cue environments, accompanied by auditory and olfactory stimuli, and ended by repeating the initial neutral room.	Participants in the *binge drinking group* reported significantly higher craving compared with *non-binge drinking students* in the kitchen and party environments. However, there were no significant differences in craving in the bar, argument, or neutral environments. The *binge drinking group* reported higher levels of thinking about drinking compared with the *non-binge drinking group* in the bar and party situations, but not in the neutral environments. Ratings of attention to the sight and smell of alcohol were not statistically significant.
Hyun, Hyun, Churl, Hoon, and Won (2013)	To reduce alcohol cravings and explore changes in brain activity due to VRT.	N = 19 Two groups: Alcohol dependence group (n = 7) Healthy control group (n = 12)	AUDIT, BDI, BAI, OCDS, Korean-BAS/BIS, Hanil Alcohol Insight Scale, TCI, VAS, PET-CT	Three: *Relaxation* (5 min, landscape); a *high-risk situation* (10 min, restaurant); and an *aversive situation* (10 min, people vomiting after drinking).	N/A	After detoxification for 7 d (lorazepam and thiamine), participants underwent PET-CT before and after VRT with repetition of the three scenes (relaxation, high-risk situation, and aversive situation). This	Patients with AUD showed increased brain metabolism in the basal ganglia and decreased metabolism in the anterior cingulate cortex compared with healthy controls, indicating that patients with AUD had elevated sensitivity to alcohol cues and reduced emotional control, respectively. After 10 VRT sessions, there was decreased metabolism in the basal ganglia of patients with AUD.

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Table 1 (*continued*)

Study (by date)	Aims	Sample (age ± standard deviation)	Instruments (questionnaires)	VR environments	VR hardware	Procedure	Results
						protocol was repeated for 10 sessions.	
Spagnoli, Gatti, Massari, Sacchelli, and Riva (2014)	To use VR protocol as an assessment tool in patients with AUD (assess self-efficacy and motivation for change).	*N* = 50 Patients with AUD Age 43.48 ± 10.88 yr Divided into 2 groups: Experimental (*n* = 25) and control (*n* = 25).	SCID GSE MAC2-A	4 virtual scenes: *Pool*, *apartment*, *office*, and *restaurant*.	1. HMD Vuzix iWear VR829 video eyewear with tracker; 2. Computer; 3. Gamepad with 2 joysticks.	The experimental group was submitted to the SCID and VR protocol (4 VR environments) and the control group was submitted to the SCID only. Before and after assessment, all patients were evaluated for their motivation to change and level of self-efficacy.	There were significant differences between groups as regards post-evaluation self-efficacy. The experimental group showed greater self-efficacy ($F_{(1,49)} = 11.120$; $p = 0.002$). However, there were no statistically significant differences between groups in motivation for change. Because of the main effect of greater self-efficacy in the experimental group, partial improvements were found in motivation for change. *The authors suggest the VR protocol can be used to assess patients with AUD.*
Choi and Lee (2015)	To reduce alcohol cravings using a VCS technique.	*N* = 40 Participants were divided into 2 groups: HSDs (*n* = 20) LDs (*n* = 20)	AUDIT *Assessment of explicit attitudes toward alcohol use*: AUQ *Assessment of implicit alcohol craving* using: alcohol IAT, Eye-tracking test, Alcohol-Stroop test	Two: *A virtual hospital* and a *virtual subway*	eMagin Z800 HMD	Baseline measurements were administered: IAT test, eye-tracking test, and Stroop. Next, VSC treatment was delivered, consisting of 10 min exposure to each VSC environment. Finally, the baseline measurements were repeated.	HSDs showed a greater reduction in subjective craving after VSC than LDs [$t_{(18)} = 5.11$, $p = 0.01$]. IAT: HSDs had a weaker positive association with alcohol after VCS than LDs [$t_{(17)} = 3.84$, $p = 0.01$]. Eye-tracking: both groups had decreased bias scores after VCS exposure [$F_{(1,29)} = 4.71$, $p = 0.05$]. Stroop: both groups showed a decreased reaction time to alcohol-related cues [$F_{(1,35)} = 5.57$, $P = 0.05$]. *Both HSDs and LDs showed treatment effects from VSC.*
Son et al. (2015)	To use VRT to treat individuals with AUD.	*N* = 30 Participants were divided into 2 groups: Alcohol-dependent individuals (*n* = 15; age 49.3 ± 9.5 yr) Healthy controls (*n* = 15; age 45.6 ± 5.9 yr)	AUDIT, BDI-II, BAI, OCDS, VAS-C, PET-CT	Three: *Relaxation* (landscape), *high-risk situation* (restaurant), and an *aversive situation* (people vomiting after drinking).	3D monitor	The VRT program was delivered for 10 sessions (twice/week) and consisted of repeating 3 VR scenes: Relaxation, high-risk, and aversive	AUDIT, BDI, and OCDS scores were higher in dependent than control individuals. There was a significantly lower score in VAS after VRT. There was a significant difference in the VAS-C score before and after VRT ($z = -2.94$, $p < 0.05$) in individuals with AUD. In addition, participants with AUD showed greater brain metabolism at baseline measurement compared with healthy controls. *Post-treatment assessment of individuals with AUD showed decreased brain metabolism compared with the baseline imaging.*

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Table 1 (*continued*)

Study (by date)	Aims	Sample (age ± standard deviation)	Instruments (questionnaires)	VR environments	VR hardware	Procedure	Results
						situations. A pre–post treatment imaging assessment was administered with PET-CT. 12 alcohol-dependent individuals completed the VRT program.	
Kim and Lee (2015)	To assess craving using a VAAT.	*N* = 36 Participants were divided into 2 groups: HSDs (*n* = 18; age 21.94 ± 3.23 yr) LDs (n = 18; age 2.33 ± 1.60 yr)	AUDIT, BDI, VAAT (32 trials with 2 instructions [push, pull] and 2 situations [alcohol, non-alcohol]).	VAAT containing *alcohol/non-alcohol situations* (drinking beer with friends in a pub versus scenes of drinking juice with friends in a café).	N/A	After the VAAT, a green or red signal appeared on the screen. The *push condition*: Participants approached the alcohol/non-alcohol situations by pushing the joystick. The *pull condition*: Participants moved away from the situations by pulling the joystick.	There was a significant difference with regard to severe depression (BDI) between the HSD and LD groups ($t_{(34)} = 2.27$, $p < 0.01$). The HSDs had higher levels of depression than the LDs. HSDs demonstrated significantly greater difficulty when withdrawing from alcohol-related situations compared with LDs ($F_{(1,\ 16)} = 14.01$, $p < 0.01$).

AA, Alcoholics Anonymous; AUQ, Alcohol Urge Questionnaire; OCDS, Obsessive-Compulsive Drinking Scale; PACS, Penn Alcohol Craving Scale; VR, virtual reality.

ADS, Alcohol Dependence Scale; AUD, alcohol use disorder; EPI, Eysenck Personality Inventory; GSE, Generalized Self-Efficacy Questionnaire; HMD, head-mounted display; IDS-42, Inventory of Drinking Situation 42; MAC2-A, Motivation Assessment of Change; N/A, not applicable/not mentioned in the text; SCID, Structured Clinical Interview for DSM-IV Axis 1 Disorders; VAS, visual analog scale; VR, virtual reality.

AAS, Alcohol Attention Scale; AASE, Alcohol Abstinence Self-Efficacy Scale; ADS, Alcohol Dependence Scale; AUD, Alcohol Use Disorder; HMD, head-mounted display; OCDS, Obsessive-Compulsive Drinking Scale; PQ, Presence Questionnaire; VAS, visual analog scale; VR, virtual reality.

AUDs, alcohol use disorders; CBT, cognitive-behavioral therapy; EEG, electroencephalography; nVRTP, non-VRT participants; HMD, head-mounted display; VAS, visual analog scale; VR, virtual reality; VRT, virtual reality therapy; VRTP, virtual reality therapy patients.

AUD, alcohol use disorder; AUDIT, Alcohol Use Disorder Identification Test; BDI, Beck Depression Index; BAI, Beck Anxiety Inventory; GSE, Generalized Self-Efficacy Questionnaire; HMD, head-mounted display; Korean-BAS/BIS, Behavior Activation System/Behavior Inhibition System; MAC2-A, Motivation Assessment of Change; N/A, not applicable/not mentioned in the text; OCDS, Obsessive-Compulsive Drinking Scale; PET-CT, positron emission tomography-computed tomography; SCID, Structured Clinical Interview for DSM-IV Axis 1 Disorders; TCI, Temperament and Character Inventory; VRT, virtual reality therapy.

AUD, alcohol use disorder; AUDIT, Alcohol Use Disorders Identification Test; AUG, Alcohol Urge Questionnaire; BAI, Beck Anxiety Inventory; BDI, Beck Depression Index; IAT, Implicit Association Test; HMD, head-mounted display; HSDs, heavy social drinkers; LDs, light drinkers; OCDS, Obsessive-Compulsive Drinking Scale; PET-CT, positron emission tomography-computed tomography; VAS, visual analog scale; VSC, virtual covert sensitization; VRT, virtual reality therapy.

AUDIT, Alcohol Use Disorders Identification Test; BDI, Beck Depression Index; HSDs, heavy social drinkers; LDs, light drinkers; N/A, not applicable/not mentioned in the text; VAAT, Virtual Approach-Avoidance Task.

Table 2
Summary of studies exploring the effectiveness of virtual reality exposure therapy.

Author (year)	Type[a]	VR therapy[b]	Number of sessions/session spacing[c]	Subjective craving treatment outcomes	Neurophysiological correlates of treatment outcomes[d]
Kwon et al. (2006)	Q	VR-CET	8 (2/w)	Alcohol craving diminished after 8 sessions	N/A
Lee et al. (2007)	Q	VR-CET	8 (2/w)	VRT led to a decrease in alcohol craving after 8 sessions	N/A
Lee et al. (2009)	E	VRT-CET, CBT, education	10 (2/w)	High reduction in alcohol craving after 10 VRT sessions	Increased EEG alpha power after 10 VRT sessions
Hyun et al. (2013)	E	VRT-CET	10 (2/w)	VRT led to a decrease in craving	VRT led to a decrease in brain metabolism after 10 VRT sessions
Son et al. (2015)	E	VRT-CET	10 (2/w)	The VRT program reduced craving	A decrease in brain metabolism was interpreted as a result of VRT

[a] Q - quasi-experiment, E – experiment.
[b] Therapies implemented: VRT-CET - virtual reality cue-exposure therapy, CBT - cognitive-behavioral therapy.
[c] Treatment was twice/week.
[d] N/A - not applicable, EEG – electroencephalogram.

alcohol craving before and after VRE. In addition, behavioral insights were provided by Choi and Lee (2015) using a virtual covert sensitization technique to weaken alcohol biases and decrease reaction time to alcohol-related cues. Likewise, Kim and Lee (2015) administered a virtual approach-avoidance task to explore reaction or latency responses to an alcohol stimulus (i.e., to measure approach/avoidance tendencies) in individuals with heavy drinking. Besides self-report instruments and behavioral measurements, several studies also attempted to obtain physiological indicators. For example, Lee et al. (2009) explored craving using pre-post VRET electroencephalography (EEG) to observe changes in brain activity. In addition, Son et al. (2015) and Hyun et al. (2013) used positron emission tomography-computed tomography (PET-CT) to evaluate brain metabolism pre-post 10 VRET sessions.

3.4. VR environments

VR environments were created according to relevant contexts and alcoholic beverages in different societies. For example, Lee et al. (2007) and Kwon et al. (2006) used Japanese-style pubs as representative contexts in their research protocols. By contrast, Ryan et al. (2010) and Bordnick et al. (2008) used hotel bars or party environments as representative of Western cultures. Some studies (Kwon et al., 2006) have reported the creation of settings designed to simulate real-life situations after exhaustive interviews with relevant populations, a procedure commonly used to develop ecologically valid and relevant VR environments (Reger, Gahm, Rizzo, Swanson, & Duma, 2009). Likewise, VR environments were also based on relevant stimuli; for example, using alcohol cues such as soju, which is a popular alcoholic drink in South Korea (Son et al., 2015).

3.5. Research results

In studies of VR as an assessment tool, Ryan et al. (2010), Lee et al. (2008), Bordnick et al. (2008), and Cho et al. (2008) obtained interesting results on social pressure related to drinking behaviors. Peer pressure (using a VR avatar) in a social context could induce greater craving than an alcohol cue itself (Cho et al., 2008) in healthy individuals with no history of AUD. Likewise, a virtual approach-avoidance task confirmed that heavy social drinkers had difficulties in moving away from alcoholic stimuli and had approach tendencies toward them (Kim & Lee, 2015). These studies explain why individuals tend to consume larger amounts of alcohol when they are accompanied than when they are alone. In the VR literature, context and cues are vital elements in eliciting arousal and Ryan et al. (2010) suggested that binge drinking college students experienced greatest craving only in alcohol-related environments. In contrast with preceding reports, Lee et al. (2008) found that social pressure was not significant in clinical populations, stating that alcohol cues induced greater craving. Similarly, Bordnick et al. (2008) indicated that individuals with AUD reported greater craving with alcohol-related cues than with neutral cues. In addition, two studies (Gatti et al., 2008; Spagnoli et al., 2014) concluded that VR-based assessment of patients with AUD was more exhaustive than classical clinical interviews based on the Structured Clinical Interview for the Diagnostic and Statistical Manual, Fourth Edition, Axis 1 Disorders, (SCID), (First, Spitzer, Gibbon, & Williams, 1996). Hence, VR-based assessment yielded greater insights into patient self-efficacy and motivation for change.

Studies on VR as a treatment tool have revealed useful insights into the effectiveness of VRET, both at self-report and physiological levels. Self-reported questionnaires in studies by Lee et al. (2007) and Kwon et al. (2006) obtained lower craving scores, indicating that alcohol craving decreased as a result of eight VRET sessions. These results were further supported by the results obtained by Choi and Lee (2015), who observed a high reduction in alcohol bias scores for heavy social drinkers in the implicit association test, Stroop test, and eye-tracking test

after virtual exposure, which can be interpreted to indicate decreased alcohol craving. Studies by Son et al. (2015), Hyun et al. (2013), and Lee et al. (2009) showed changes in brain metabolism and alpha waves after VRET using PET-CT and EEG. After 10 VRET sessions, imaging techniques revealed decreased brain activity related to alcohol cues, which was interpreted as reduced craving for alcohol.

In a comparison of VRET and cognitive-behavioral therapy (CBT) based on alpha brain activity in EEGs, Lee et al. (2009) found that VRET was more effective in reducing alcohol craving than CBT. These authors showed that alcohol cue reactivity was associated with diminished frontal alpha activity after VRET in dependent patients. They also mentioned that the activation of subcortical-limbic area at baseline was replaced by the activation of superior temporal gyrus after VRET. Later studies (Hyun et al., 2013; Son et al., 2015) reported a decreased metabolism in basal ganglia in AUD patients after VRET compared to baseline, which the authors attribute to its possible effect on limbic-regulated responses to reward. These studies reported a decrease in alcohol craving after VRET. The outcome effects of these studies are summarized in Table 2.

4. General discussion

The studies presented in this review provide significant preliminary evidence in support of VR as an assessment and treatment tool in individuals with alcohol misuse. Interestingly, studies that used an avatar to exert social pressure showed that greater craving was triggered by social pressure than by alcohol stimuli in healthy individuals. Conversely, regardless of social pressure, individuals with AUD experienced greater craving when exposed to alcohol-related virtual situations than when exposed to neutral situations. This supports the cue and context dependency assumption regarding alcohol craving.

The studies reviewed have used devices that offer differing levels of immersion, ranging from low immersion systems such as 2D projectors or stereoscopic monitors, through intermediate systems like stereoscopic projectors to systems based on HMDs (Head Mounted Displays) which achieve the highest levels of immersion. However, the studies that have incorporated HMDs have not made use of advanced models, and so the levels of immersion applied are much lower than those that can be achieved today thanks to the reduction in costs and the increase in the quality of the instruments in recent years. It is worth noting, however, that several of the studies reviewed incorporated devices that also affect the level of immersion through senses other than vision: for example, through hearing (using multi-channel sound systems) or through smell. In any case, the relationship between the level of immersion of VR systems and their effectiveness as instruments for evaluating or treating patients with alcohol abuse has not been studied directly. In general one might expect there to be a positive linear relationship between the two variables, but this may not be the case under certain conditions (Gutiérrez-Maldonado, Pla-Sanjuanelo, & Ferrer-García, 2016). The most immersive devices, such as HMDs, cause discomfort after prolonged use and are also associated with adverse effects such as simulation sickness (dizziness, nausea, dry eyes, etc.) which can impair their effectiveness. A particularly interesting line of research in the future would be the systematic study of the levels of immersion required to achieve different assessment and treatment aims, taking into account the observations made above regarding the suitability of the various devices.

Three studies (Hyun et al., 2013; Lee et al., 2009; Son et al., 2015) used virtual exposure based on aversive therapy (individuals vomiting as a consequence of drinking alcohol) to disrupt drinking habits. Although the main objective was accomplished in all three studies—that is, a reduction in alcohol cravings—the aversive therapy caused dropouts. For example, three participants dropped out of the study by Son et al. (2015) because treatment induced negative memories associated with the aversive environment.

Nevertheless, all studies implementing subjective, physiological, or both types of assessment indicated that VRET effectively reduces alcohol craving. Brain imaging techniques revealed important clinical outcomes, adding vital information concerning the effectiveness of VRET. In addition, evidence of decreased brain metabolism and increased EEG alpha power after VRET can be taken to indicate its capacity to reduce alcohol craving.

However, this review shows that research performed to date has some limitations. First, comparisons of VRT with other treatments have been conducted, but we recommend the design of studies which incorporate larger clinical samples and comply with the CONSORT guidelines. Second, the study samples varied from healthy individuals to binge drinking college students, light and heavy social drinkers, Alcoholic Anonymous members, and participants diagnosed with AUD, so extrapolations for AUD patients must be made with caution. The clinical samples were small, but the results were generally consistent with each other. The social pressure variable, which was emphasized in the work by Cho et al. (2008) and Lee et al. (2008), is of great interest in the study of the triggers of alcohol craving. Questions such as how many avatars should be included in a VR setting and what type (i.e., interactive or drinking) should be addressed in future studies in clinical samples; also, a distinction should be made between light and heavy drinking individuals. Finally, none of the studies conducted a follow-up examination of the long-term effects of VRT. Given the growing interest in applying VR technology to treat substance use disorder (SUD), more studies are required to fully determine its effectiveness. Future research should implement VR in larger clinical samples and conduct clinical trials and follow-up studies. Although there is an urgent need for more research applying VR in AUD, the 13 studies included in this review provide promising results. This is particularly important because many patients experience at least one relapse in the first year following treatment (Charney, Zikos, & Gill, 2010), and VR technology may be able to complement existing methods.

Thanks to its ecological validity VR is arousing increasing interest among clinicians and researchers (Ferrer García & Gutiérrez Maldonado, 2012). VR permits the presentation and strict control of stimuli of a real-life situation (Valmaggia, Latif, Kempton, & Rus-Calafell, 2016), and represents a significant advance in individualized assessment and treatment options in AUD (Hone-Blanchet et al., 2014). Prolonged exposure leads to a habituation process, which implies less arousal toward alcohol-related stimuli and less craving. In addition, exposure enables patients to build coping strategies for future real-life situations. VR techniques are based on the same principles as traditional cognitive-behavioral treatments, but they also increase the possibility of transferring the learning results achieved during treatment sessions to the patient's real everyday environment. This is possible thanks to the high degree of control of the parameters of exposure that virtual simulations can achieve and, at the same time, the high degree of similarity between the learning context and the real situation in which the patient must deal with the stimuli that provoke alcohol consumption. In these two areas – the increase in the degree of control over the parameters of exposure, and the simulation of real contexts in which alcohol consumption occurs – VR techniques can help to improve the procedures for assessment and treatment available at present.

5. Conclusions

The studies presented in this review suggest that VR offers benefits in the assessment and treatment of alcohol craving and achieves high levels of ecological validity. The results were generally consistent, showing positive effects in the context of several assessment indicators and underlining the usefulness of VRET. These results indicate the need for clinical trials following the CONSORT guidelines, follow-up studies and testing variables such as level of immersion and social pressure in triggering craving in order to determine the long-term effects of VRET.

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Contributors

Authors Alexandra Ghiţă and José Gutiérrez Maldonado conducted literature searches, selected the studies included in the systematic review, were both implicated in writing the manuscript and have approved the final version of the manuscript.

Conflict of interest

Both authors declare that they have no conflicts of interest.

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