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Assessing reactivity to virtual reality alcohol based cues

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Abstract

The use of virtual reality (VR) programs in behavioral science research has been gaining prominence over the past several years. In the field of substance abuse, VR cue reactivity programs have been successfully tested for feasibility in nicotine and cocaine dependent samples. Seeking to expand VR applications in alcohol cue research, a novel VR alcohol cue reactivity assessment system incorporating visual, auditory, and olfactory stimuli was developed and tested. In a controlled trial, 40 non-treatment-seeking drinkers with alcohol use disorders were exposed to VR alcohol cue environments. Subjective craving, attention to alcohol cues, and level of presence (realism of experience) in VR were assessed across the environments. Overall, subjective craving for alcohol increased across the VR alcohol-related cue environments versus VR neutral cue environments. Participants reported high levels of presence in VR, indicating that the environments were perceived as realistic and compelling. These initial findings support the use of VR based cue reactivity environments for use in alcohol cue-based treatment and research.

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In the US, according to the 2004 National Survey on Drug Use and Health, approximately 18.7 million people age 12 and older are classified with dependence on or abuse of alcohol ([Substance Abuse and Mental Health Services Administration, 2005](#)). An estimated 7.5 billion dollars are spent on alcohol treatment each year ([National Institute on Alcohol Abuse and Alcoholism, 2001](#)) in the United States. However, relapse

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rates remain high with most patients having 2 treatment admissions per year (SAMHSA, 2001). Given the high rates of relapse, increasing prevalence rates, and mortality, new treatment approaches that address biological, psychosocial, and environmental factors need to be developed in order to increase abstinence rates and reduce relapse.

A widespread method for assessing the impact of cues (triggers) related to alcohol use is referred to as cue reactivity study. Cue reactivity to alcohol-related cues is thought to be based in part on classical conditioning theory (Pavlov, 1927; Tiffany, 1995). In classical conditioning theory, reactivity to cues involves conditioned responses triggered by environmental cues such as people, places, odors, or situations related to past drug or alcohol consumption (Childress et al., 1993; O'Brien, Childress, McLellan, & Ehrman, 1993; Prakash & Das, 1993; Satel, 1992; Wallace, 1989; Washton, 1987). Over time it is assumed that these stimuli, by virtue of their pairing with the unconditioned drug stimulus, become conditioned stimuli capable of eliciting conditioned responses in the form of reactions such as increased craving, skin responses, and heart rate. Presumably, these cue-specific reactions reflect motivational processes responsible for continuing drug use in addicts as well as relapse in addicts attempting to remain abstinent.

Traditionally, laboratory-based cue reactivity studies consisting of simple cue presentations suggest that visual, auditory, olfactory, and tactile cues can increase physiological arousal, subjective urges, and craving in those who abuse alcohol (Carter & Tiffany, 1999; Cooney et al., 1997; Drummond & Glautier, 1994; Glautier & Drummond, 1994; Hutchinson et al., 2001; Laberg & Ellertsen, 1987; Monti et al., 1993a,b). Monti and Rohsenow (1999) reported that relapse can often be brought about by a constellation of complex cues including mood state, social interactions, and drinking materials.

Seeking to expand beyond simple cue presentations to more realistic environments, researchers have constructed bars in the laboratory or conducted experiments in real bars to study actual drinking contexts. Often actors (confederates) are used as bar patrons, servers, and/or peers to simulate drinking interactions and experiences. Laboratory-based bars have been used to study medication effects, cue reactivity, and alcohol use expectancies in social and dependent drinkers (Anton, Drobos, Voronin, Durazo-Avizu, & Moak, 2004; Drobos, Anton, Thomas, & Voronin, 2003; Fromme & Dunn, 1992; Wall, McKee, & Hinson, 2000; Wall, McKee, Hinson, & Goldstein, 2001; Wigmore & Hinson, 1991). During experiments, ratings of alcohol expectancies are obtained in a variety of contexts (real bar vs. lab bar). In trials, participants report higher alcohol expectancies in the real bars compared to laboratory-based bars (Wall et al., 2000, 2001). These studies highlight the role of context and the need to expand cue-based research methods to incorporate more ecologically valid experimental environments.

Given the importance of cues in alcohol use and relapse, the potential for incorporation of cues into treatment approaches may be important. However, in trials with alcohol drinkers, cue exposure based intervention results are mixed and efficacy tends to be modest following treatment (Havermans & Jansen, 2003). In treatment trials, cue exposure has been tested alone (Drummond & Glautier, 1994) or combined with coping skills, cognitive behavioral, or social skills interventions (Cooney, Baker, & Pomerleau, 1983; Drummond & Glautier, 1994; Monti et al., 1993a; Rohsenow et al., 2001). Data across treatment trials suggest that cue exposure combined with coping skills training may result in increased use of skills, increases in days abstinent, and decreases in drinking (Monti & Rohsenow, 1999; Rohsenow et al., 2001). Niaura (2002) contends that coping skills need to be acquired and practiced in contexts that are congruent with real world environments where drug or alcohol use occurs; in addition, developing cue exposure methods based on technologies that provide real world simulations, such as virtual environments, are proposed to advance this technique into treatment and research settings.

Cue reactivity and exposure have been widely used in addiction research and treatment. However, current cue methods (e.g., laboratory-based bars or visiting real bars) are limited by the following which may impede progress: issues of repeatability and control; variation between labs and subjects; costs; time to conduct experiments; difficulty changing the settings or contexts; availability of actors or extras; issues of confidentiality, safety, and liability; and space needed for creating bars in the lab. In addition, research review boards often consider using real liquor and bars unethical. All of these issues can be efficiently addressed using the knowledge and techniques borrowed from virtual reality exposure programs used in other disorders.

1. Virtual reality

Since the late 1990s, virtual reality has been gaining acceptance for use in medical training applications and in treatment of psychological disorders. VR methods have gained clinical acceptance and are currently in use for specific phobias, pain management, eating disorders, and post-traumatic stress disorder (Anderson, Rothbaum, & Hodges, 2001). In past clinical treatment trials, participants reported emotional and physiological arousal when immersed in VR, thus providing a tool for exposure in the treatment of psychological disorders (Muhlberger, Herrmann, Wiedemann, Ellgring, & Pauli, 2001; Rothbaum, Hodges, Smith, Lee, & Price, 2000; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001; Wiederhold, Davis, & Wiederhold, 1998; Wiederhold & Wiederhold, 2001). The generalization of VR treatment results to actual functional activities in daily life represents a milestone for VR, providing tangible benefits which extend outside of the virtual reality environments (Rizzo, Wiederhold, & Buckwalter, 1998).

Building on VR programs from other fields, VR programs have been developed for use in substance abuse studies. An early VR application for exposure to opiate cues has been described by Kuntze et al. (2001). Pilot data indicated participants experienced increased urges to use (Kuntze et al., 2001). Seeking to advance the use of VR for substance abuse research, a novel VR cue reactivity program for nicotine cues was developed and tested (Bordnick & Graap, 2004; Bordnick, Graap, Copp, Brooks, & Ferrer, 2005; Bordnick et al., 2004; Bordnick, Traylor, Graap, Copp, & Brooks, 2005). This VR program integrated videos of actual people into the VR environments, allowing participants to experience complex social interactions. Initial studies with nicotine dependent participants demonstrated that VR based nicotine cues and social interactions [i.e., Virtual Reality Based Nicotine Cue Reactivity Assessment System (VR-NCRAS), Bordnick & Graap, 2004] led to significant increases in both physiological reactivity and subjective craving (Bordnick, Graap, Copp, et al., 2005; Bordnick, Traylor, et al., 2005).

Based on the data from previous pilot trials in VR nicotine cue reactivity research, a new VR alcohol cue reactivity assessment system (VR-ACRAS) (Bordnick, Graap, Brooks, & Ferrer, 2005) was developed. The VR-ACRAS described in this investigation offers standardized exposure to stimuli with zero variation between presentations of cues, experimental trials, and research settings. The current research study is the first to use VR to provide specific and complex cues, including social interactions, for alcohol cue investigation. Additionally, this study includes the use of olfactory stimuli in a novel controlled delivery system to add another dimension to the cue experience. In the current investigation, we hypothesized that adults with alcohol use disorders exposed to VR alcohol stimuli would experience significant increases in subjective craving and attention to alcohol cues compared to their reactions to VR neutral stimuli. We also predicted that participants will report high levels of presence post VR exposure.

2. Materials and methods

2.1. Participants

Thirty-two male (80%) and eight female (20%) non-treatment seeking participants with alcohol use disorders were recruited through newspaper advertisements and a television news story in the metro-Atlanta area. To participate, the following inclusion criteria were met: DSM-IV-TR (American Psychiatric Association, 2000) diagnosis of alcohol abuse or dependence, self-reported good physical health, 6th grade or higher English reading level, and ability to wear a VR helmet for up to 40 min. Exclusion criteria included DSM-IV-TR (American Psychiatric Association, 2000) diagnosis of severe mental illness or other substance dependence (nicotine not included), self-reported current use of psychotropic or anti-craving medications, pregnancy, history of seizures or seizure disorders, self-reported use of illicit drugs in the past 30 days, or other significant health problems that would preclude participation.

The participants were 68% African American ($n=27$) and 32% Caucasian ($n=13$). They ranged in age from 23 to 60 years, with a mean age of 39.5 years ($SD=10.1$). Eighty two percent ($n=33$) of the participants met criteria for alcohol dependence and 18% ($n=7$) met the criteria for alcohol abuse. Drinking levels averaged 5.1 ($SD=3.1$) drinks consumed per day. Fifty three percent ($n=21$) of the participants were non-smokers and 47% ($n=19$) were daily smokers. Average smoking levels were 13.6 ($SD=8.4$) cigarettes or cigars per day. Data for one participant on the amount smoked per day was missing.

2.2. Measures

2.2.1. Intake/screening

2.2.1.1. Alcohol and drug use history. A screening interview designed to assess basic alcohol and drug use was administered by a Ph.D.-level clinician. Information on past and current use of alcohol, tobacco, and other drugs was assessed.

2.2.1.2. Structured clinical interview for the DSM-IV-TR (American Psychiatric Association, 2000).

The DSM-IV-TR interview was used to screen participants for alcohol diagnostic criteria and rule out other potential major psychiatric diagnoses.

2.2.2. VR trial

2.2.2.1. Alcohol craving. A single item visual analog craving scale projected on a white background into the VR rooms was used to measure subjective craving for alcohol. Participants rated their current level of craving intensity on a scale that ranged from 0 (not at all) to 100 (more than ever). The craving VAS scale has been used to measure craving in VR (Bordnick, Graap, Copp et al., 2005; Bordnick et al., 2004; Bordnick, Traylor et al., 2005) and traditional cue reactivity studies (Cutler, 2005; Johnson, Chen, Schmitz, Bordnick, & Shafer, 1998; Preston & Jasinski, 1991).

2.2.2.2. Attention to cues. A modified version of the Alcohol Attention Scale (AAS) (Monti et al., 1993b) was projected into VR rooms and used to measure attention to alcohol cues. Participants rated their level of attention to alcohol on 11-point scales ranging from 0 (*didn't notice at all*) to 10 (*completely paid attention*) for the following 2 items "How much did you pay attention to the sight of alcohol in the

room?” and “How much did you pay attention to the smell of alcohol in the room?” A third question addressed thoughts about drinking on a scale anchored by 0 (*didn't think about drinking at all*) and 10 (*thought about drinking all the time*) for the following item “How much did you think about drinking alcohol while you were in the room?” The 3-item AAS scale has been used to measure attention to actual alcohol beverages in cue reactivity studies (Hutchinson et al., 2001).

2.2.2.3. Realism/presence. Post VR trial, a modified Presence Questionnaire (PQ) based on Witmer and Singer (1998) was used to assess the degree of realism, involvement and interactions, and naturalness of the VR experience (Witmer & Singer, 1998). Assessment of presence using the PQ is specifically suited for VR and can represent the degree to which the participant experiences the computer generated environment as similar to the real place (Witmer & Singer, 1998). Participants rated 15 questions on 7-point scales. Total scores range from 15 to 105, with higher scores indicating a greater sense of presence in the virtual environment.

2.3. Olfactory cue scent system

The Scent Palette™ (Envirodine Studios, Inc. Canton, GA) system was used to present olfactory cues. The Scent Palette system is a USB device controlled by the computer that allows scent to be presented based upon pre-programmed triggers within the VR environment (e.g., walking up to a smoker and smelling cigarette smoke). Scents used in the VR-ACRAS included vanilla, pizza, coffee, whiskey, scent of preferred drink of participant (whiskey, beer, brandy, tequila, gin, scotch, red wine, white wine), beer, cigarette smoke, and pine trees. In two instances, participants' preferred drink was vodka, which was not used due to its relative lack of odor, so their second preferred drink, beer, was substituted.

2.4. VR-ACRAS environments

The neutral cue environment was devoid of all alcohol cues and consisted of a gallery of four aquarium scenes with video, sounds, and vanilla scent. The vanilla scent served as a neutral stimulus to control for the effect of scent in the alcohol environments.

The bar cue environment consisted of a typical hotel bar setting. While in the bar, the participant observed a person ordering and consuming a drink. The participant then proceeded past tables with alcoholic beverages to the bar. The virtual bartender interacted with the participant by asking for their order, and serving them their pre-selected beverage of choice. Upon placement of the beverage on the bar, a scent cue was presented to match the type of drink served (e.g., beer, scotch, or wine scent). Alcohol scents were also presented upon encountering various objects and drinks on tables.

The kitchen environment contained inanimate cues consisting of party preparation items placed on counters. Participants moved around the counters and stopped at various places displaying alcohol-related cues such as limes and soda, and overt alcohol cues such as liquor bottles and cases of beer. Scents were presented at various places congruent with the visual cues.

The argument environment was developed to create a negative socially awkward situation and consisted of a home office where two people were drinking and arguing. The people interacted with participants by trying to draw them into the disagreement and asking them to mediate the argument. After minimal participation, the participant was asked to leave the couple alone, due to “not being helpful.” Alcohol scents were presented when the participant approached the couple, both of whom were drinking.

The party environment consisted of indoor living and dining rooms and outdoor deck patio areas of a home where people were eating, smoking, and drinking. Participants interacted with the virtual partygoers and were offered a drink. Alcohol scents were presented when encountering alcoholic beverages, pizza scent was presented at a food table, and outdoor scent and cigarette smoke were presented on the patio area where people were smoking and drinking.

The final VR room encountered was identical to the first neutral room. The same environment was used for both neutral presentations to decrease novelty effects. Screen shots of all VR-ACRAS cue environments are depicted in Fig. 1.

To avoid the potential of cross cue reactivity or contamination between alcohol and nicotine cues, the bar, kitchen, and argument rooms were specifically designed to be devoid of smoking cues and smoke scent. The party environment was the only scenario that contained people smoking and smoke scent. To control for carryover effects of experiencing alcohol and nicotine cues, the VR party was the last alcohol environment presented.

2.5. Design and procedures

Participants responding to advertisements recruiting volunteers for a study on alcohol craving contacted the research center by telephone and provided verbal consent to participate in a 15-minute phone interview to assess initial eligibility and reduce the likelihood that unsuitable participants would undergo a full assessment before being excluded. Eligible participants were scheduled for an intake-screening visit and were instructed not to drink alcohol for at least 12 h before their visit. They were informed that a breath

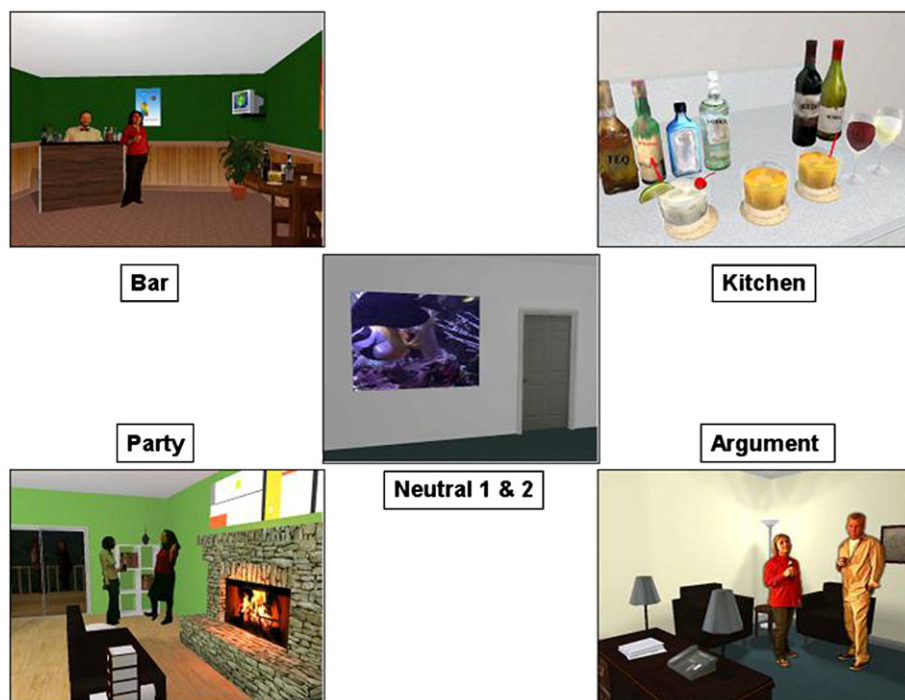


Fig. 1. VR-ACRAS environments.

alcohol sample would be collected and if alcohol was detected (any reading over 0.00) they would not be eligible to participate. Participants who smoked were asked not to smoke for 1 h before their visit.

Upon arrival at the Virtual Reality Clinical Research Center (VRCRC), participants were provided study information including rationale, risks, potential benefits, and the role of the IRB. All participants provided consent in writing before further participation. After consent was obtained, a breath alcohol sample was collected. No participants were excluded during this procedure. Participants then completed pencil and paper assessment instruments and interviews with a Ph.D.-level clinician to assess full study eligibility. After completion of intake screening, all eligible participants underwent a 15-minute VR acclimation session to provide familiarity with an unrelated VR experience, the projected visual analog scales, operation of input devices, and the study procedures. The VR environment used during this initial procedure was devoid of alcohol cues and was unrelated to the alcohol craving environment. After completing the acclimation session, participants were instructed to take a 15 minute break and asked not to smoke.

Upon returning to the lab, participants were seated in a comfortable chair placed upon a vibration platform (Virtually Better, Inc. Decatur, GA) and were asked to again wear the VR head mounted display and tracker (HMD; VFX-3D, Interactive Imagining Systems, Rochester, NY). After adjusting the helmet for comfort and testing for operation, participants were given a wireless game pad (P3000, Saitek, Torrance, CA) to allow input of subjective responses during the cue reactivity trial. Instructions were read from a standard script for participation during the cue trial to the participant wearing the VR equipment, and questions, if any, were answered. The ambient lighting was turned off, and through a graphical interface, the VR experimental path and each participant's preferred alcoholic beverage and accompanying scent were pre-set. The interface allowed the cue environments to be individualized with beverage of choice, so that the sight and smell of the preferred alcoholic beverage selected appeared in the VR alcohol cue environments along with other alcoholic beverages and scent. The VR-ACRAS (Bordnick, Graap, Brooks et al., 2005) program was started with a 5 minute baseline phase in which participants listened to classical music while the HMD screens remained dark. The baseline was designed to allow participants to relax and to decrease pre-trial distractions. After the 5-minute baseline phase, participants were asked to stand and the cue reactivity trial began. The VR-ACRAS program guided participants along a pre-programmed track at timed intervals to standardize exposure to cues and interactions within the VR environments. The order of presentation to cue rooms was neutral room 1, bar, kitchen, argument, party, and neutral room 2. Each room lasted 3 min, for a total of 18 min of exposure in VR. To control for order effects and time in VR, participants were randomized to one of two paths that allowed the bar and kitchen to be switched to control for social cues or inanimate cues being presented first. After each cue environment, participants used a game pad to rate their craving intensity and their attention to cues on visual analog scales displayed within the VR environment to maintain immersion.

At the end of the VR-ACRAS session, a post trial debriefing interview was conducted by a Ph.D.-level researcher. Participants were asked a set of standardized questions related to their subjective experiences in the VR environments. Questions focused on room specific interactions (e.g., Describe your experience in the bar environment). In addition, participants completed the Presence Questionnaire, an assessment of their level of presence in the VR environments.

2.6. Data analysis

2.6.1. Primary

Repeated measures analysis of variance (ANOVA) methods were used to compare the effect of VR cue rooms on subjective craving. A separate ANOVA was used to compare the effect of VR cue rooms on the

3 alcohol attention scales. For all analyses, violations of sphericity were checked using the Mauchly's test. Following the significant main effects for the craving or attention variables, post hoc pairwise tests were conducted using Bonferroni corrections to determine which of these variables differed by cue room.

2.6.2. Secondary

To compare the effects of current drinking levels on craving, participants were grouped using a percentile ranking into low (less than 3 drinks per day), medium (4–6 drinks per day), and high (7 or more drinks per day) levels of drinking. Craving levels were compared between the low, medium, and high groups in the VR cue rooms using ANOVA.

To test the effects of potential cross cue reactivity between nicotine and alcohol, participants were grouped into smokers and non-smokers and craving level were compared between VR rooms. In addition, the effect of gender on craving was compared between VR cue rooms.

3. Results

3.1. Craving

A significant main effect of VR cue rooms (neutral 1, kitchen, bar, argument, party, neutral 2) on subjective craving was found ($F(4, 146)=71.31, p<.001$). Because the assumption for sphericity was not met, a Huynh–Feldt correction was used. After the significant main effect, pairwise comparisons indicated that alcohol craving ratings for the VR party, bar, kitchen, and argument rooms were significantly higher than neutral 1 and neutral 2 VR rooms. As depicted in Fig. 2, mean (SD) craving ratings for the kitchen, bar, and party alcohol cue rooms were not significantly different from each other, showing similar reactivity. Craving ratings in the argument room were significantly lower compared to the other alcohol cue rooms ($p<.005$). Craving ratings in neutral rooms 1 and 2 were not significantly different from each other.

Because VR is a relatively new cue presentation method, craving effect sizes were calculated using d , which is the difference between craving means divided by their pooled standard deviation Cohen (1988).

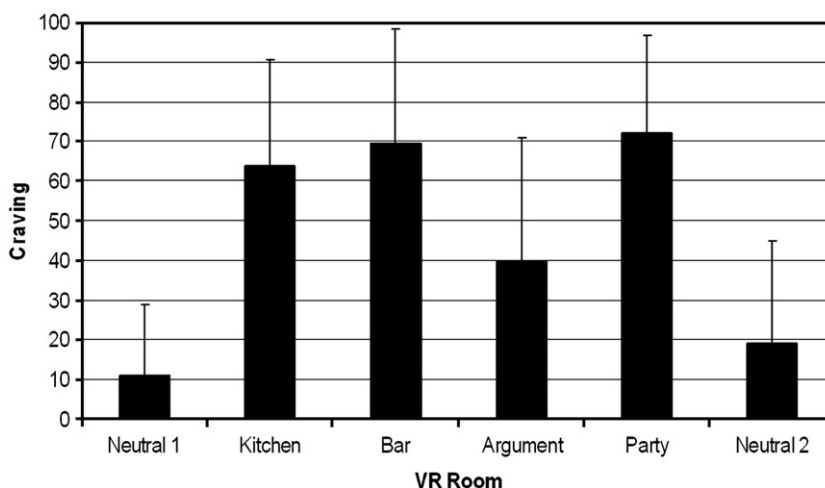


Fig. 2. Average alcohol craving ratings across VR cue rooms.

Table 1
Mean alcohol attention scale ratings for each item across VR cue rooms

AAS Item	Neutral 1 M (SD)	Kitchen M (SD)	Bar M (SD)	Argument M (SD)	Party M (SD)	Neutral 2 M (SD)
Sight of alcohol	0.20 (0.46) _a	9.0 (1.9) _b	8.4 (2.3) _b	5.6 (3.1) _b	7.5 (2.3) _b	0.73 (2.1) _a
Smell of alcohol	0.73 (1.7) _a	6.9 (3.1) _b	6.9 (3.1) _b	5.3 (3.5) _b	7.1 (3.1) _b	1.4 (2.5) _a
Thoughts about drinking	1.3 (1.9) _a	7.9 (2.5) _b	8.0 (2.6) _b	4.7 (3.4) _c	7.9 (2.3) _b	2.1 (2.8) _a

Note: Scores on the AAS items for sight and smell range from 0 (didn't notice at all) to 10 (completely paid attention), and for thoughts from 0 (didn't think about drinking at all) to 10 (thought about drinking all the time). VR rooms in each row that do not share the same subscript letter differ at $p < .05$.

This estimation of effect size is, therefore, in terms of standard deviation units. Cohen (1988) has described effect sizes of .2, .5, and .8 as small, medium and large effect sizes. The craving effect sizes found in this study (comparing alcohol cue rooms to neutral rooms) ranged from 1.70 to 2.45. The average effect size, combining craving scores across all three alcohol rooms and both neutral rooms (and excluding the argument room) was 2.19.

3.2. Attention to cues

Three separate repeated measures ANOVA were conducted for each of the alcohol attention scale items. For all three ANOVAs, the sphericity assumptions were not met, so Huynh–Feldt corrections were used. Significant main effects for VR cue rooms were found on sight ($F(4,142)=184.00, p < .001$), smell ($F(4, 168)=74.8, p < .001$), and thought ($F(4,145)=94.5, p < .001$) items. Overall pairwise comparisons

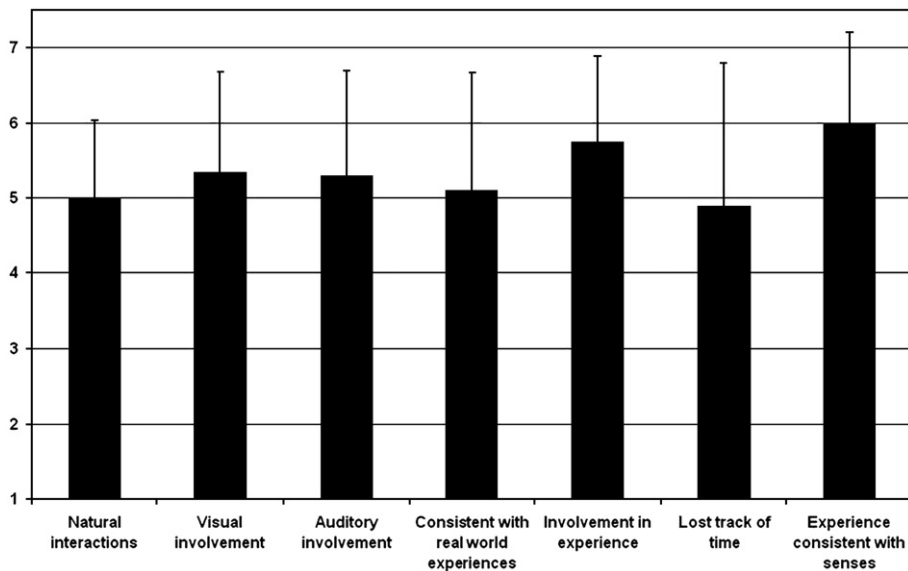


Fig. 3. Average rating on PQ items.

for each of the three separate alcohol attention scale items (sight, smell, thoughts) indicated that scores were greater in the bar, kitchen, party, and argument rooms compared to the neutral rooms ($p < .05$). For the sight and smell attention items, no significant differences were found between alcohol cue rooms. Attention to thoughts about drinking in the argument room were significantly lower compared to the other alcohol cue rooms ($p < .001$). Attention items were not significantly different between the neutral rooms 1 and 2. Average scores for each of the AAS across the VR rooms are presented in [Table 1](#).

No significant differences were found on craving in the VR cue rooms based on level of drinking, smoking status, or gender.

3.3. Presence/realism

To assess the degree of presence of the VR-ACRAS environments, average scores for participants on the seven PQ items and overall total scores were calculated. The overall total mean score on the PQ was 81.7 (SD=11.3). Average presence ratings for individual items related to realism and involvement in VR are depicted in [Fig. 3](#).

4. Discussion

This study demonstrates that the VR-ACRAS system is capable of generating significant increases in subjective alcohol craving when drinkers are exposed to VR alcohol cues compared to neutral VR cues. Our findings are notable for the effect sizes generated by alcohol cue VR environments. [Carter and Tiffany \(1999\)](#) in their meta-analysis reported that cue reactivity effect sizes for smokers, heroin and cocaine addicts were approximately one standard deviation (1.0). However, they found alcohol studies had a much smaller effect size, approximately .5 standard deviations. In contrast, the effect sizes found here averaged approximately 2.0 standard deviations. A clear difference between past cue reactivity studies and the present study is the nature of the cue presentation. Traditional methods were simple presentations of alcohol cues. In contrast, this study employed a complex, multi-sensory environment. However, it remains unclear whether the complexity of cue presentation can account for these differences in effect sizes. A future study, where cue complexity is varied, is needed to shed light on this possibility. Nevertheless, a cue presentation method that can generate an effect size of approximately two standard deviations is a valuable tool for future research because experimental manipulations of this larger effect will be easier to detect.

A significantly lower craving response was found in the argument room, a room designed to create a negative, socially awkward experience. This finding may indicate that although specific cues were present, either the negative interaction, the incongruence of the situation compared to the other VR alcohol rooms, or other contextual factors in this room may have affected craving intensity. Further supporting this notion are the significantly lower ratings on “thoughts about drinking” in this room compared to other VR alcohol rooms. More specifically, participants interviewed after the cue trial indicated a perceived threat from the actions of the couple arguing. Additional studies using VR cue environments are needed to provide insight into the specific impact of mood and contextually based social interactions (positive and negative) on craving and thoughts about drinking.

To further assess the potential impact and realism of the VR experience, participants rated the VR environments in the current trial using seven items from the PQ. All ratings indicated high degrees of perceived reality or presence. Presence can be conceptualized as the degree of involvement a person has in

the VR environment, encompassing their sensory interactions, attention, and how realistically the experience mimics real world interactions (Witmer & Singer, 1998). These ratings demonstrated that the VR-ACRAS experience was consistent with the participants' *real world* interactions. In addition to the PQ measures, interview data collected post trial during debriefing revealed that participants experienced real world emotions in the VR settings, suggesting that the context created in the VR-ACRAS was congruent enough with their previous real world experiences. For example, over 20 (50%) of participants reached out to pick up the virtual alcohol drinks and were frustrated when this failed, and several participants indicated that they felt comfortable with the people at the party and wanted to interact more. This finding is novel for VR cue reactivity and suggests that future VR systems should incorporate other modes of sensory experience (e.g., haptics, increased interactions) to improve realism. Increasing realism is an important factor for future studies comparing VR-ACRAS to traditional cue lab studies where participants can handle actual drinks. One would expect that handling an actual drink would be more realistic than picking up a virtual drink, but we contend that a lab bar does not offer a congruent drinking context compared to a virtual bar which places the participant in an actual bar setting outside of the lab space. However, research comparing traditional cue methods to VR can offer knowledge on the importance of environmental context in cue reactivity. In general, VR-ACRAS has the potential to offer greater congruence and verisimilitude, without being an exact match to the experience of any one participant. The ability to handle an actual drink notwithstanding, these data suggest that well designed VR environments can capture enough cues and enough of the environmental context to elicit emotions in participants that mimic those which they may experience in the real world.

This study demonstrated consistent and increased craving to VR alcohol cues in a community sample of participants with alcohol use disorders. Additional studies will need to examine VR-ACRAS cues and environments in different populations. Fortunately, VR-ACRAS allows complete replication in other samples to be run in future studies. In addition, studies comparing VR cue exposure to real life cue exposure and traditional cue exposure paradigms are needed to determine the potential benefits of this new methodology. We caution that our results do not diminish research supporting traditional cue methods. However, if results in future studies demonstrate that VR cue reactivity is equal to traditional methods, then VR can offer greater utility, decreased costs, decreased time to conduct experiments, various settings or contexts selected by mouse click, no ongoing need for actors or extras, increased confidentiality, and increased safety.

One issue raised with VR approaches is the potential cost to set up and operate a system. The costs of VR technology have been decreasing with the advent of faster computers and peripherals that are widely marketed. Depending on the type of system and options selected, a VR system capable of running VR cue trials can be built from \$9,000–\$25,000 (USD). As with other technologies, improvements in the quality and flexibility of VR programs including lower costs are expanding with each generation of computer hardware and programming tools, thus providing affordable solutions for researchers and clinicians.

While the results of the current study are clearly promising, the following limitations need to be addressed in future studies. First, the use of subjective measures must be considered. As with most studies on cue reactivity, subjective ratings are used to measure craving. Single item craving ratings are limited by reliability and validity concerns (Tiffany, Carter, & Singleton, 2000). The VAS measure used in the current investigation was selected in order to limit outside distractions that may affect immersion. Future studies should incorporate objective measures associated with craving changes (e.g., heart rate, skin conductance and brain imaging) that could provide further support for this measure.

Second, the lack of biochemical drug screens to verify recent use of other drugs at screening and after the 15 minute break before testing must be addressed. In this study, self-report alcohol and drug diagnostics assessment of current and past use were conducted by trained clinicians. Participants may have been using other drugs that were not reported in the interview. In addition, there was no verification other than verbal report that participants did not smoke during the 15 minute break before testing. However, it is unclear how some participants smoking a cigarette at this time would have significantly affected the results. Future studies should incorporate biochemical verification methods at screening and before testing sessions.

Finally, the current sample consisted of alcohol abusing or dependent non-treatment-seeking drinkers. VR-ACRAS studies need to be conducted in different age groups, contexts, drinking levels, treatment seeking, and in polysubstance users living in both urban and rural areas to expand generalizability beyond the current sample.

Future uses of VR-ACRAS outside of cue exposure assessment of craving range from providing a method for exposure in extinction trials to teaching relapse prevention and coping skills in cognitive behavioral therapy. Specifically, VR would allow patients in treatment settings to experience arousal and reactivity, develop new coping skills, repeat exposures, and practice skills in real-time in the safety and confidentiality of the professional's office. The addition of VR to substance abuse treatment and research will expand the potential of cue exposure and coping skills based interventions by providing a means to customize treatment to fit the patient's needs or specific skill deficits. Current VR designs allow the therapist to control aspects of exposure stimuli, including presentation order, repetition, and timing. Therapists using VR can tailor situations to suit individual participants. For example, a participant could be presented with cues related to social interaction involving drinking, such as offers to drink and non-verbal cue behaviors suggesting a need to have a drink. Variables such as context, type of stimuli (brand of alcohol or drink type), social group, gender, cultural group, and other factors can be pre-programmed into VR environments as required and selected through the computer keyboard or graphical interface by the professional. A communication link between the professional and patient allows the professional to encourage skill practice and monitor physiologic response using additional measurement tools. The system described above is currently being tested in a clinical trial for nicotine dependence to teach coping skills and relapse prevention strategies to patients for smoking cessation.

In conclusion, the current study demonstrates that virtual reality based alcohol cues are capable of eliciting craving in current drinkers. Further testing is warranted to investigate the utility of VR in cue reactivity research and treatment areas. We envision that this initial study will provide the framework to utilize VR cue methods and extend current traditional cue paradigms to explore the role of environmental context and complex cues on drug craving and relapse. Currently, the use of virtual reality programs in addiction research and treatment is limited, but these results merit further testing and exploration.

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