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Feasibility of Using Virtual Reality to Assess Nicotine Cue Reactivity During Treatment

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Abstract

Cue reactivity assessments have been widely used to assess craving and attention to cues among cigarette smokers. Cue reactivity has the potential to offer insights into treatment decisions; however, the use of cue reactivity in treatment studies has been limited. This study assessed the feasibility of using a virtual reality–based cue reactivity assessment approach (VR-NCRAS) during treatment. In a clinical smoking cessation treatment study, 46 treatment-seeking nicotine-dependent adult smokers were assessed for cue reactivity at baseline, Week 4, and Week 10 of treatment. Measures of cue reactivity included subjective craving and attention to cues after exposure to two neutral and two smoking cue environments. Overall, feasibility of using VR-NCRAS was demonstrated and these findings support the use of the cue reactivity assessment during treatment, which can inform treatment decisions.

Keywords

nicotine; cue reactivity; craving; virtual reality; smoking

Cue reactivity is a concept used in substance abuse research which posits that drug-dependent individuals are vulnerable to drug use when in the presence of stimuli associated with the previous use of the drug (Carter & Tiffany, 1999). The dominant framework for understanding cue reactivity, classical conditioning, explains that drug-dependent individuals have conditioned reactions to stimuli or cues associated with previous substance abuse, and these reactions increase the risk for relapse and maintain drug use (Carter & Tiffany, 1999; LaRowe, Saladin, Carpenter, & Upadhyaya, 2007; Niaura et al., 1988; Rohsenow et al., 2001; Rohsenow, Niaura, Childress, Abrams, & Monti, 1990). Typically assessed in laboratories, cue reactivity is demonstrated by presenting different types of cigarette and neutral cues to smokers and measuring levels of reactivity including craving and attention. Smokers are presented with photographs of smoking paraphernalia or given actual cigarettes and lighters to hold. A limitation often cited with traditional assessments is their inability to incorporate complex, realistic cues involving combinations of social

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Declaration of Conflicting Interests

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situations and interactions, affective experiences, and physical cues (Traylor, Bordnick, & Carter, 2008). Traditional assessments may also have limited ability to simulate real-world experiences, thus limiting their ecological validity. However, the incorporation of technology such as the use of virtual reality (VR) may address some of the limitations of traditional cue reactivity assessment methods.

Virtual Reality

VR is a technology medium that goes beyond viewing images on a computer screen or one-way interactions that occur in a video game. VR uses computer graphics and input devices to create a simulation designed to immerse a user in the virtual environment mimicking the “real world.” A typical VR system uses a head-mounted display to present the virtual environment and a tracking device allows the user to look around as if they were in the environment. Additional sensory input devices used to increase immersion include tactile sensors allowing users to handle virtual objects (e.g., cigarettes, beer bottle), spatial audio for surround sound, and a scent machine which provides olfactory stimuli (e.g., cigarette smoke, pizza, whiskey).

In substance abuse research, VR has been used to expand the breadth and complexity of traditional cue presentation (e.g., static photographs) methods by integrating computer graphics with a head-mounted display, head-tracking devices, audio, vibrotactile, and olfactory stimuli (Bordnick et al., 2009). It allows for immersing participants in multisensory realistic environments that may lead to similar reactions in the individual as would be experienced in the real world (Baumann & Sayette, 2006). VR has the ability to incorporate complex cues involving combinations of social interactions, contexts, affective experiences, and physical cues, which simulate real-world settings. Incorporating cues more closely resembling a smokers’ real-world experience leads to a greater and more accurate display of cue reactivity (Monti & MacKillop, 2007), which enhances generalization outside the lab (Niaura et al., 1988). VR provides a method for researchers to study addiction severity and test potential interventions in realistic, controlled environments (Culbertson, 2010).

Bordnick and colleagues (Bordnick et al., 2004) developed a standardized virtual reality nicotine cue reactivity assessment system (VR-NCRAS). The VR-NCRAS has been used in multiple nicotine studies with nontreatment seeking smokers (Bordnick, Graap, Copp, Brooks, & Ferrer, 2005; Bordnick, Traylor, Graap, Copp, & Brooks, 2005; Traylor et al., 2008). Studies using this novel VR approach have consistently reported increased subjective craving responses after exposure to smoking cues as compared to neutral cues (Bordnick et al., 2004; Bordnick, Graap et al., 2005; Bordnick, Traylor et al., 2005; Traylor et al., 2008). The next logical step is to incorporate VR-based cue reactivity assessment into treatment. Expanding VR cue reactivity into treatment would provide clinicians with a controlled method to assess progress and help clients practice coping skills in high-risk situations (Bordnick, 2010).

Clinical Utility of Cue Reactivity Assessments

Cue reactivity assessments can be used to index addiction severity and to assess the impact of pharmacological or psychological treatments (Carter & Tiffany, 1999; Drummond, 2000). This process is of significant relevance because cue reactivity is associated with relapse even long after quitting (Ferguson & Shiffman, 2009). However, few studies have assessed cue reactivity spanning treatment (Carter & Tiffany, 1999; LaRowe et al., 2007) because a majority of nicotine cue reactivity studies have primarily included nontreatment seeking samples, (Hussain et al., 2010; Niaura et al., 2005; Tiffany, Cox, & Elash, 2000) or else they assess cue reactivity before administering pharmacological interventions and then reassess shortly after (Ferguson & Shiffman, 2009; Shiffman et al., 2003; Waters et al., 2004). In treatment settings, the incorporation of VR cue reactivity assessment can offer access to real-world environments in the clinic and provide valuable clinical benefits and insight during therapy for both clinicians and clients. Specifically, cue reactivity assessment can offer a reliable method to assess and identify relapse triggers, pinpoint deficits, and foster therapeutic discussions. Thus, the aim of the current study is to determine the feasibility of using the VR-NCRAS through a 10-week treatment process.

Method

Participants

Participants ($n = 46$) were recruited through advertisements in a local paper in the Atlanta metropolitan area and were involved in a treatment study. Demographic characteristics of the sample are presented in Table 1. The following were the inclusion criteria for study participation: (a) cigarette smokers with current *Diagnostic and Statistical Manual, Fourth Edition, Text Revision* (DSM-IV-TR; American Psychiatric Association, 2000) diagnosis of nicotine dependence, who were daily smokers for the past 2 years; and (b) good physical health and willing to wear a nicotine patch. The following were exclusion criteria: (a) current DSM-IV-TR (American Psychiatric Association, 2000) psychiatric diagnosis of chronic, severe mental illness (e.g., schizophrenia, bipolar disorder, depression with psychosis, and schizoaffective disorder), or substance abuse other than nicotine dependence; (b) treated with any smoking cessation, (c) history of serious medical conditions (e.g., heart condition); (d) fear of closed spaces or visual problems that may impair ability to view VR materials.

Design and Procedures

After obtaining informed consent, a member of the research team administered questionnaires, rating scales, and a smoking history, which assessed years smoking, number of quit attempts, and current and past use levels. After completion of the assessments, participants were provided with a health assessment by a nurse to ensure ability to use nicotine replacement therapy (NRT) Nicoderm CQ™ patch, smoking level for Nicoderm CQ™ 10-week program, and to confirm overall health status. Participants were provided over-the-counter (OTC) NicodermCQ™ patches by a licensed nurse. Dosing schedule followed GlaxoSmithKline's recommendation of a 21-mg patch for Weeks 1–6, 14-mg patch for Weeks 7–8, and 7-mg patch for Weeks 9–10. Participants were then instructed to

return to the clinic weekly, for the duration of the study, to meet with the nurse to receive new nicotine patches and complete assessments.

Treatment Conditions

The study design was a randomized two-group design. Participants were randomly assigned to two treatment conditions. Condition 1 (NRT only) group received NRT patches and weekly nursing visits. Condition 2 (NRT + behavioral therapy) received patch and weekly behavioral smoking cessation therapy. Since the purpose of this study is to determine the feasibility of using VR-NCRAS rather than treatment modality, both groups were combined into one group for analysis.

Cue Reactivity Assessment

At baseline (before receiving nicotine patch), Week 4, and Week 10, all participants were assessed for cue reactivity using the VR-NCRAS (Bordnick et al., 2004). Upon arrival at the research center, participants underwent a 15-min VR acclimation session to help provide familiarity with the VR experience, assessment scales, and study procedures. A 10-min break was given after VR acclimation in the lab, during initial VR-NCRAS assessment. Participants then entered the testing room and were seated in a comfortable, nonreclining chair placed upon a vibration platform (Virtually Better, Decatur, GA). Participants were asked to put on a VR head-mounted display and tracker (eMagin, Hopewell Junction, NY). Participants held a game pad controller (P3000, Saitek, Torrence, CA) in their dominant hand to allow for responses on the visual analog scales at the end of each cue room. The ambient lighting was then turned off and the VR experimental path, including each participant's preferred cigarette brand type in the VR smoking environments, was preselected. Participants then relaxed for 5 min, with classical music playing while the screens were dark, until the VR-NCRAS trial began.

All participants were exposed to two neutral and two smoking cue environments, with two smoking environments counterbalanced. Exposure was 3 min for each environment with participants being led through the environment on a timed path. After presentation of each environment, participants completed self-report craving and attention ratings, using a game pad hand controller. Rating scales were projected into the VR environment.

Assessments

Craving

A single-item visual analog craving scale was used to measure cigarette craving. Participants rated their current level of craving in response to the prompt, "Indicate your greatest craving for smoking," by selecting a position along a line anchored on the left by *not at all* and on the right by *extremely*.

Smoking Attention Scale (SAS)

The SAS is a modified version of the 3-item Alcohol Attention scale, (Hutchison et al., 2001) with appropriate adjectival modification for smoking questions. Participants rated their level of attention to smoking cues on a scale 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 cigarettes in the room?” and “How much did you pay attention to the smell of cigarettes in the room?” A third question addressed thoughts about smoking on a scale anchored by 0 (*didn’t think about smoking at all*) and 10 (*thought about smoking all the time*) for the following item, “How much did you think about smoking while you were in the room?” The SAS scale has been used to measure attention to smoking and alcohol cues in VR studies (Bordnick et al., 2004; Bordnick, Graap, et al., 2005; Bordnick et al., 2008; Bordnick, Traylor et al., 2005; Traylor, Bordnick, & Carter, 2009; Traylor et al., 2008).

VR-NCRAS Environments

Neutral

The neutral cue environment consisted of a digital art gallery in which participants can look around without the presence of smoking cues. The room had two screens on each side that displayed nature videos. The videos were approximately 1.25 min each. The same neutral cue room was used for both neutral cue presentations.

Smoking Paraphernalia

The smoking paraphernalia environment consisted of a room in a house, including a home bar area and a living room scenario containing furniture, with various smoking cues on tables including packs of cigarettes of users’ preferred brand, alcoholic beverages, coffee, ashtrays, and burning cigarettes. This room contained no social interactions or people.

Smoking Party

The party environment consisted of a house party where participants were exposed to people drinking, eating, and talking, with alcoholic drinks and smoking stimuli (cigarettes, cigarette packs) on tables and cigarette offers from other guests. Screenshots of the VR party environment are presented in Figure 1.

Olfactory Stimuli

The Scent Palette™ (EnviroDine Studios, Atlanta, GA) was used to present olfactory stimuli. The Scent Palette is a universal serial bus computer controlled device that delivers scent into the cue environments using gelled scents that are triggered by the VR software. For example, when walking by a cigarette smoker at a party the device emits cigarette smoke scent. During the cue assessment cigarette smoke, raw tobacco, and pizza scents were presented in the smoking party and paraphernalia environments. In the neutral environment, fresh flower scent was presented. After scents are presented, fans cleared the residual scent to avoid carryover effects.

Data Analysis

A repeated measures analysis of variance (ANOVA) was performed on each assessment time point (intake, Week 4, and Week 10) with VR condition (Neutral 1, Party, Paraphernalia, and Neutral 2) as the within-subject factor. Post hoc tests were performed on individual means from the four VR conditions within each assessment time to determine

significant differences. Dependent variables were craving to smoke and attention to cigarette cues (sight of cigarettes, smell of cigarettes, and thinking about smoking).

Results

Craving

Intake—There was a main effect of VR condition on craving to smoke, $F(3, 135) = 19.5$, $p < .0001$, partial $\eta^2 = .303$, indicating participants reported greater craving in some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated significantly higher craving occurred during party and paraphernalia conditions compared to either neutral condition. There were no significant differences between party and paraphernalia, nor between the two neutral conditions. (The same is true of all subsequent analyses unless otherwise noted.)

Week 4—There was a main effect of VR condition on craving to smoke, $F(3, 135) = 9.5$, $p < .0001$, partial $\eta^2 = .174$, indicating participants reported greater craving in some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated significantly higher craving occurred during party and paraphernalia conditions compared to either neutral condition.

Week 10—There was a main effect of VR condition on craving to smoke, $F(3, 135) = 2.96$, $p = .035$, partial $\eta^2 = .062$, indicating participants reported greater craving in some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated significantly higher craving occurred during party and paraphernalia conditions compared to the second neutral condition. There were no other significant differences. Craving ratings across treatment are presented in Figure 2.

Attention to Cigarette Cues

Sight of Cigarettes

Intake—There was a main effect of VR condition on attention to cigarette cues, $F(3, 135) = 190.9$, $p < .0001$, partial $\eta^2 = .809$, indicating participants paid greater attention to cigarette cues following some VR conditions compared to others.

Week 4—There was a main effect of VR condition on attention to cigarette cues, $F(3, 135) = 65.7$, $p < .0001$, partial $\eta^2 = .593$, indicating participants paid greater attention to cigarette cues following some VR conditions compared to others.

Week 10—There was a main effect of VR condition on attention to cigarette cues, $F(3, 135) = 34.5$, $p < .0001$, partial $\eta^2 = .434$, indicating participants paid greater attention to cigarette cues following some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated, at all assessment time points, significantly higher attention to cigarette cues during both the party and paraphernalia conditions compared to either neutral condition.

Smell of Cigarettes

Intake—There was a main effect of VR context on attention to the smell of cigarettes, $F(3, 135) = 55.3, p < .0001$, partial $\eta^2 = .551$, indicating participants paid greater attention to the smell of cigarettes during some VR conditions compared to others.

Week 4—There was a main effect of VR context on attention to the smell of cigarettes, $F(3, 135) = 34.7, p < .0001$, partial $\eta^2 = .435$, indicating participants paid greater attention to the smell of cigarettes during some VR conditions compared to others.

Week 10—There was a main effect of VR context on attention to the smell of cigarettes, $F(3, 135) = 17.6, p < .0001$, partial $\eta^2 = .281$, indicating participants paid greater attention to the smell of cigarettes during some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated, at all assessment time points, significantly higher attention to the smell of cigarettes during both the party and paraphernalia conditions compared to either neutral condition.

Thinking about Smoking

Intake—There was a main effect of VR context on thoughts about smoking, $F(3, 135) = 45.6, p < .0001$, partial $\eta^2 = .503$, indicating participants thought more about cigarettes during some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated significantly higher thoughts about smoking during both the party and paraphernalia conditions compared to either neutral condition.

Week 4—There was a main effect of VR context on thoughts about smoking, $F(3, 135) = 30.3, p < .0001$, partial $\eta^2 = .402$, indicating participants thought more about cigarettes during some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated significantly higher thoughts about smoking during both the party and paraphernalia conditions compared to either neutral condition.

Week 10—There was a main effect of VR context on thoughts about smoking, $F(3, 135) = 10.1, p < .0001$, partial $\eta^2 = .183$, indicating participants thought more about cigarettes during some VR conditions compared to others. Post hoc analyses, conducted on differences among VR conditions (at $\alpha < .05$), indicated significantly higher thoughts about smoking during both the party and paraphernalia conditions compared to either neutral condition. Attention ratings across treatment for sight, smell, and thoughts are presented in Figure 3.

Discussion

The primary goal of this study was to explore the feasibility of using the VR-NCRAS to assess craving and attention across treatment. The feasibility and utility of VR-NCRAS as part of an ongoing clinical assessment plan in treatment was demonstrated. In general, basic cue reactivity effects were found at baseline, midpoint of treatment, and end of treatment for craving and attention to cues between neutral and smoking cue environments. In support of ongoing assessment of craving and cue reactivity is a recent study by Carter and colleagues (Carter et al., 2009), which reported that ex-smokers continued to experience increased

craving after exposure to smoking cues even after 2 weeks of abstinence. Thus, using VR-based exposure in treatment can allow clinicians to adapt treatment to individual needs and bring up discussion of potential skill deficits that remain in spite of abstinence.

VR-based cue exposure and assessment can offer a standardized clinical tool appropriate for both clinical and research settings. Specifically, the VR-based programs offer the following advantages:

1. Provides immersion in visual, auditory, and sensory environments without unexpected and unwanted outside distractions from the real world.
2. Allows exposure to realistic complex cues and social interactions.
3. Offers the ability to provide exposure and assessment of proximal, contextual, and social cues.
4. Allows full control and predictability for professionals employing exposure.
5. Provides communication in real time, offering opportunities to assess skills and relapse risks.
6. Offers the ability to duplicate and repeat complex cue situations including social environments and social interactions, in order to measure client change in responses.
7. Involves simple interface controls for novice users.
8. Uses time frames for assessment ranging from seconds to minutes for flexibility of measurement goals.
9. Automates and completes assessments using the game pad, reducing recording errors.
10. Has the potential to add and expand assessment tools beyond craving and attention to other clinical variables.

Overall, VR-based cue exposure and assessment can advance current nicotine-dependence treatment and provide a validated platform for treatment and research applications.

The results of the current study must be considered with the following limitations. The primary measures were self-reported craving and attention to cues. As with all measures based on self-report, there is the possibility of bias in data collection. However, in cue reactivity assessment, self-report is the current standard for measuring craving and attention in the literature. The generalizability of the current findings is limited, since the study was conducted in a southern metropolitan city, and the sample may not be characteristic of smokers in other areas.

In accordance with translational research moving work from the laboratory to the clinic, the use of cue exposure in the laboratory as a research tool can now be used as an assessment during treatment and provide clinicians critical information to prevent relapse. The richness of the cue environment presented here provides the opportunity for clinicians and clients to identify relapse triggers that may be individual in nature. For example, one smoker may

experience higher craving in social situations, while another smoker may find isolated cigarette packs more troublesome. In practice, social workers and health professionals can use VR cue exposure assessment to guide treatment and assess relapse risk during clinical sessions. Specifically, clinicians can then tailor or adjust treatment to focus on the individual client's specific triggers and help decrease the risk of relapse.

In summary, nicotine studies using cue reactivity exposure assessments across treatment have been scarce. Exploring cue reactivity among smokers in treatment over longer periods of time is warranted to assess continued increased risk for relapse. This study demonstrates the feasibility of using the VR-NCRAS across treatment to assess cue reactivity. Future studies are needed to explore the use of the VR-NCRAS as an assessment of nonpharmacological treatments aimed at reducing cue reactivity, including coping skills and similar cognitive behavioral therapy approaches, to further validate the VR-NCRAS's ability to detect changes in reactivity over time, and to explore the differences among psychological treatments on reducing cue reactivity long term. In conclusion, VR-based cue reactivity measures can offer clinicians and clients an expanded method to assess the impact of proximal, contextual, and complex cues in simulations of real-world relapse situations.

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Figure 1. Screenshots of the virtual reality (VR) party environment. (a) Smokers on patio, (b) Offer to smoke, and (c) Indoor party.

Figure 2.
Craving for the four cue rooms at baseline, midpoint, and posttreatment.

Figure 3. Attention to cues (sight, smell, and thoughts) for the four cue rooms at baseline, midpoint, and posttreatment.

Table 1Participant Demographics and Smoking Data ($N = 46$)

Variable	<i>M</i>	<i>SD</i>
Age	46.93	9.27
Cigarettes per day	25.54	7.83
Years smoking at current rate	16.76	10.16
Age started smoking	17.72	5.38
Past quit attempts	2.98	3.17
Daily cigarettes smoked past 30 days	22.48	6.97
Variable	<i>N</i>	%
Sex		
Male	24	52.2
Female	22	47.8
Race		
Caucasian	5	10.9
Black	39	84.8
Hispanic	1	2.2
Other	1	2.2