Published in final edited form as:

Addict Behav. 2011 July ; 36(7): 696–699. doi:10.1016/j.addbeh.2011.01.029.

Cue Reactivity in Virtual Reality: The Role of Context

Megan M. Paris^{a,d}, Brian L. Carter^{a,c,*}, Amy C. Traylor^{b,a}, Patrick S. Bordnick^c, Susan X Day^d, Mary W. Armsworth^d, and Paul M. Cinciripini^a

^a The University of Texas M.D. Anderson Cancer Center, Department of Behavioral Science – Unit 1330, 1515 Holcombe Blvd, Houston TX 77019

^b The University of Alabama, School of Social Work, 210 Little Hall, PO Box 870314, Tuscaloosa, AL 35487-0314

^c University of Houston, Graduate College of Social Work, 110HA Social Work Building, Houston TX 77204-4013, Phone: 713-743-1798

^d University of Houston, College of Education, 214 Farish Hall, University of Houston, Houston, TX 77204-5023

Abstract

Cigarette smokers in laboratory experiments readily respond to smoking stimuli with increased craving. An alternative to traditional cue-reactivity methods (e.g., exposure to cigarette photos), virtual reality (VR) has been shown to be a viable cue presentation method to elicit and assess cigarette craving within complex virtual environments. However, it remains poorly understood whether contextual cues from the environment contribute to craving increases in addition to specific cues, like cigarettes. This study examined the role of contextual cues in a VR environment to evoke craving. Smokers were exposed to a virtual convenience store devoid of any specific cigarette cues followed by exposure to the same convenience store with specific cigarette cues added. Smokers reported increased craving following exposure to the virtual convenience store without specific cues, and significantly greater craving following the convenience store with cigarette cues added. However, increased craving recorded after the second convenience store may have been due to the pre-exposure to the first convenience store. This study offers evidence that an environmental context where cigarette cues are normally present (but are not), elicits significant craving in the absence of specific cigarette cues. This finding suggests that VR may have stronger ecological validity over traditional cue reactivity exposure methods by exposing smokers to the full range of cigarette-related environmental stimuli, in addition to specific cigarette cues, that smokers typically experience in their daily lives.

*Corresponding author, present address: University of Houston, Graduate College of Social Work, 110HA Social Work Building, Houston TX 77204-4013, Phone: 713-743-1798, Fax 713-743-8149, Bcarter6@uh.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

Smoking; Virtual Reality; Cue Reactivity; Craving; Gestalt Theory

---

1. Introduction

Numerous laboratory cue-reactivity studies have demonstrated that smokers report higher levels of craving when exposed to smoking cues compared to neutral cues (Carter & Tiffany, 1999). More recently, virtual reality (VR), an immersive experience that presents life-like smoking environments along with specific cues, has been used to elicit and assess cue reactivity among smokers (Bordnick et al., 2005; Traylor, Bordnick, & Carter, 2008). However, in these studies, given the complex multi-sensory presentation of VR scenarios, it remains unclear whether explicit cues (e.g., lit cigarettes) are the primary stimuli for increased craving during VR exposure. Although the power of explicit cues to evoke craving in laboratory experiments is well established, less is known about the power of other stimuli (e.g., smoking-related environments) to evoke craving in the VR world.

Conklin and colleagues (2008) investigated explicit cues alone and contextual stimuli alone (e.g., a bar scene without explicit cigarette cues) to explore craving responses in smokers. Using photographs for cue exposure, they found a significant increase in craving following exposure to the contextual stimuli which were devoid of specific cigarette cues. They also obtained smokers' reactivity to photographs of explicit cues (e.g., cigarette in an ashtray) and found significantly higher craving compared to the contextual cues. Given the complex sensory world of the smoker's natural environment, it seems likely that other stimuli, more distally associated with smoking, can induce a craving response. The findings of Conklin and colleagues (2008) also suggest that a VR immersion in a context tacitly associated with smoking can produce strong craving. For the purposes of this study, we refer to "context" as the complex, interrelated stimuli (e.g., a room where smoking is allowed) as separate from the discrete (explicit) cues such as cigarettes or other smokers.

This study examined the influence of environmental context on smokers' craving to smoke in VR. We explored smokers' craving reactivity after exposure to a context related to smoking but devoid of explicit cigarette cues. We then exposed the same smokers to the same context with explicit cigarette cues included. This comparison was designed to replicate the context findings of Conklin and colleagues (2008), but in a VR setting, and test whether explicit cues added to the context-only environment elicit additional increases in craving.

2. Method

2.1 Participants

Daily smokers ($N = 24$) at least 18 years old and smoking 10 or more cigarettes per day were recruited for the sample. Smoking status was verified with a measure of expired carbon monoxide (CO), with a value greater than 10 parts per million required for inclusion.

2.2 Procedure

The technical aspects of VR in our laboratory are described elsewhere (Bordnick, et al., 2005). Participants were guided through a presentation of four VR environments using a computerized path in which all exposure times were standardized to approximately 3 min. The four VR environments were two nature scenes, without cigarette cues or any cigarette-related environments, and two identical convenience store scenes, one devoid of explicit cigarette cues and the other with cigarette cues included. In the neutral environments, participants stood in a room designed to look like an art gallery and viewed framed 360-degree underwater scenes of active aquatic life or viewed narrated nature videos of wildlife in their natural habitats. In both convenience store environments, participants first found themselves standing next to a car parked at a gasoline pump in a gas station designed to resemble a national convenience store chain. A timed path guided participants from the gas pump into the convenience store, where a clerk behind the counter greeted participants and encouraged them to look around the store.

Both convenience store environments contained visual stimuli (e.g., store clerk, food items) and auditory stimuli (e.g., outdoor traffic noise, indoor sounds of cash register) appropriate to the context. The two convenience store scenes were identical in content and path timing with the exception of the presence of explicit cigarette cues. Participants were exposed to four discrete cigarette cues in the store with cue: a cigarette in an ashcan, a woman smoking outside the store, and two different displays of cigarette packs behind the store counter. In the store without cues, the ashcan and woman were not present, and a plain window replaced the cigarette displays. See Figure 1.

Before the VR session began, participants were seated in the experiment room and completed pre-session questionnaires (e.g., demographics, smoking history). Participants smoked one cigarette of their own brand while completing the last pre-session questionnaire to control for variability in time since last cigarette smoked.

2.3 VR Session

Participants first engaged in a brief VR acclimation session with an environment unrelated to the study (i.e., an office setting) to provide familiarity with the overall virtual experience. Self-report of craving was collected after each experimental VR scene with a single item asked aloud by the experimenter, which allowed participants to remain engaged in VR and reduced interruption in the immersive experience. The single item, "Please indicate your craving for smoking at this time," was recorded on a 10-point scale anchored by "Not at all" on one end to "More than ever" on the other.

All participants were guided through the first neutral scene followed by the store without cues; then they had a 5-min rest period before exposure to a second neutral scene followed by the store with cues, making the time from presentation of the first VR environment to the conclusion of the last environment approximately 17 min. Neutral scenes were counterbalanced so that half of the participants viewed underwater scenes during the first neutral scene while others viewed the narrated wildlife videos first. Presentation of convenience store environments was not counterbalanced to minimize the likelihood of

craving carryover effects, which are a concern in cue-reactivity studies. For example, carryover effects from initial VR smoking environments can influence craving in subsequent environments (see Traylor et al., 2008). After participants completed the final craving assessment in VR, equipment was removed, participants completed the Presence Questionnaire (Witmer, Jerome, & Singer, 2005) to provide information about their VR experience, and were paid \$40.

3. Results

3.1 Sample

Participants were 62.5% male, 37.5% female, 70.8% White, 20.8% Black, 8.3% Hispanic, had an average age of 33.1, smoked 18.6 cigarettes per day, began smoking at age 15.7, and had baseline levels of expired CO of 26.2 ppm.

3.2 Craving

Craving was indexed as the mean craving response immediately following each VR environment (first neutral, store without cues, second neutral, and store with cues). Dependent samples *t*-tests were conducted on four planned comparisons: each of the two store environments versus its preceding neutral environment, store without cues versus store with cues, and the first neutral versus the second neutral. Results are accompanied by effect size estimates using Cohen's *d* (Cohen, 1988). Craving means and standard errors for each VR environment are displayed in Figure 2.

There was a significant increase in craving between the first neutral and the store without cues, $t(23) = 5.03, p < .0001, d = 0.95$, indicating that an environmental context related to smoking, but devoid of explicit cigarette cues, also elicits craving in smokers. There was also a significant increase in craving between the second neutral and the store with cues, $t(23) = 4.44, p < .0001, d = 0.74$, which replicates our previous findings indicating an environmental context associated with smoking, with explicit cigarette cues included, elicits craving (Traylor, et al, 2008; Bordnick, et al., 2005).

There was also a significant increase in craving between the first neutral and the second neutral, $t(23) = 3.18, p < .01, d = 0.64$, indicating that, despite a 5-min rest period following the store without cues, craving remained higher than the craving reported after the first neutral environment. Furthermore, a significant increase in craving between store without cues and store with cues, $t(23) = 3.20, p < .01, d = 0.58$, indicated that the highest level of craving was evoked by the store that combined both contextual and explicit cigarette cues.

3.3 Presence Questionnaire

The PQ demonstrated good overall internal consistency and reliability with a Cronbach's alpha coefficient of .85. Participants reported a strong overall feeling of presence in the virtual environments ($M = 118, SD = 19.4$), which is similar to previous VR cue-reactivity research (Bordnick et al., 2008; Bordnick, et al, 2005).

4. Discussion

Results of this study replicated the basic cue-reactivity craving effects found in previous VR studies (Bordnick et al., 2005; Bordnick et al., 2004; Gray et al., 2008; Saladin et al., 2006; Traylor et al., 2008). The convenience store with explicit cues, compared to its preceding neutral environment, evoked significantly more craving. Results also indicated that a cigarette-related environment devoid of explicit cigarette cues evoked strong craving. This finding is consistent with Conklin and colleagues (2008), who found craving increases in smokers after exposure to pictures of environments related to smoking but devoid of explicit cigarette cues.

The potential of a craving carryover effect between the store without cues and the second neutral scene makes interpretation of this data problematic. At present, it can not be determined if the significantly higher craving found after the store with cues (compared to the store without cues) is due to the presence of specific cues or a higher baseline level of craving established by a carryover effect. Assuming the presence of a carryover effect, it appears that a smoking-related context, without explicit cues, has an equal power to evoke craving as the same environment with the explicit cues included. Perhaps explicit cues lose some of their power to evoke craving when included in the appropriate context, but when explicit cues are presented alone, craving is maximized (Conklin, et. al, 2008). In any case, the data provided here calls into question the notion that specific cigarette cues are the most powerful drivers of the craving response in the smoker's natural environment, and offers an explanation for the lack of success found in cessation treatment extinction trials using only explicit cues (Conklin & Tiffany, 2002).

Craving cue reactivity has historically been conceptualized as a classically conditioned response (Tiffany, 1995). Although some have challenged this view (Tiffany, 1990), there is near unanimous agreement that cue responses are the result of learning processes. A strong craving response in an environment devoid of explicit cues suggests environmental stimuli associated with smoking are simultaneously encoded in the learning process of establishing cue responses in smokers. If smokers have strong craving responses to contextual factors, as well as explicit cues, then these contextual stimuli are worthy of study in their own right as we attempt to gain a better understanding of the processes underlying cue reactivity.

A final consideration of the findings should be explored. When craving is evoked in the context only environment, are explicit cues *implied*? That is, when smokers are confronted with an environment that almost always includes explicit smoking cues, but these cues are absent, the smoker may assume or perceive explicit cues are present. Gestalt perceptual theory suggests this is likely, stating that people tend to fill in incomplete figures in their environment. An example comes from previous work in our VR laboratory, where smokers were exposed to a VR setting that did or did not provide olfactory cues. During debriefing, smokers who were not subjected to olfactory cues claimed confidently they experienced them (Traylor, 2007). This intriguing possibility should be explored with detailed debriefing and attention-to-cues scales (Traylor, Bordnick, & Carter, 2009) when presenting context-only VR environments.

Naturalistic studies, using hand held computers, and laboratory investigations are revealing the smoker's world as an intricately complex one. Smokers are confronted with multiple layers of stimuli including sights, sounds, smells, social situations, life stressors, and so on. VR is one of the few laboratory methods for presenting cigarette and environmental cues in a life-like manner. Therefore, VR may help narrow the divide between data obtained in the laboratory and how smokers experience life situations that influence smoking behavior in the real world.

References

- Bordnick PS, Graap KM, Copp HL, Brooks J, Ferrer M. Virtual reality cue reactivity assessment in cigarette smokers. *CyberPsychology & Behavior*. 2005; 8:487–492. [PubMed: 16232041]
- Bordnick PS, Graap KM, Copp HL, Brooks J, Ferrer M, Logue B. Utilizing virtual reality to standardize nicotine craving research: A pilot study. *Addictive Behaviors*. 2004; 29:1889–1894. [PubMed: 15530734]
- Carter BL, Tiffany ST. Meta-analysis of cue-reactivity in addiction research. *Addiction*. 1999; 94:327–340. [PubMed: 10605857]
- Cohen, J. *Statistical power analysis for the behavioral sciences*. 2. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
- Conklin CA, Robin N, Perkins KA, Salkeld RP, McClernon FJ. Proximal versus distal cues to smoke: The effects of environments on smokers' cue-reactivity. *Experimental and Clinical Psychopharmacology*. 2008; 16:207–214. [PubMed: 18540780]
- Conklin CA, Tiffany ST. Applying extinction research and theory to cue-exposure addiction treatments. *Addiction*. 2002; 97:155–167. [PubMed: 11860387]
- Gray KM, LaRowe SD, Upadhyaya HP. Cue reactivity in young marijuana smokers: A preliminary investigation. *Psychology of Addictive Behaviors*. 2008; 22:582–586. [PubMed: 19071985]
- Saladin ME, Brady KT, Graap K, Rothbaum BO. A preliminary report on the use of virtual reality technology to elicit craving and cue reactivity in cocaine dependent individuals. *Addictive Behaviors*. 2006; 31:1881–1894. [PubMed: 16516397]
- Tiffany ST. A cognitive model of drug urges and drug-use behavior: The role of automatic and non-automatic processes. *Psychological Review*. 1990; 97:147–168. [PubMed: 2186423]
- Tiffany, ST. Potential functions of classical conditioning in drug addiction. In: Drummond, DC.; Tiffany, ST.; Glautier, S.; Remington, B., editors. *Addictive behaviour: Cue exposure theory and practice*. London: Wiley; 1995. p. 47–71.
- Traylor, AC. Doctoral dissertation. 2007. Exploring cue reactivity in nicotine dependent young adults using virtual reality with expanded olfactory cues. Retrieved from WorldCat. Accession No: OCLC: 350426836
- Traylor AC, Bordnick PS, Carter BL. Assessing craving in young adult smokers using virtual reality. *American Journal on Addictions*. 2008; 17:436–440. [PubMed: 18770087]
- Traylor AC, Bordnick PS, Carter BL. Using virtual reality to assess young adult smokers' attention to cues. *Cyberpsychology & Behavior*. 2009; 12:373–378.
- Witmer BG, Jerome CJ, Singer MJ. The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments*. 2005; 14:298–312.

Convenience store devoid of smoking cues

Convenience store with smoking cues

Figure 1.
Screen shots of VR environments.
(present in color on the web, and black and white in print)

Figure 2.

Self reported craving after each VR environment. Error bars are standard errors of the mean.
(present in color on the web, and black and white in print)