



Cue reactivity in virtual reality: The role of context

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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.

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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, Graap, Copp, Brooks, & Ferrer, 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, Robin, Perkins, Salkeld, and McClernon (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 et al. (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 et al. (2008), but in a VR setting, and test whether explicit cues added to the context-only environment elicit additional increases in craving.

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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 Fig. 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



Fig. 1. Screen shots of VR environments.

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