ORIGINAL INVESTIGATION

Effects of Systematic Cue Exposure Through Virtual Reality on Cigarette Craving

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ABSTRACT

Introduction: Cigarette cravings have been associated with less successful attempts to quit smoking and a greater likelihood of relapse after smoking cessation. Background craving refers to a relatively steady and continuous experience of craving, while cue-induced craving refers to phases of intense craving triggered by cues associated with smoking. Cue exposure treatment (CET) involves repeated exposure to stimuli associated with substance use in order to reduce craving responses. However, mixed results have been found regarding the effect of CET on both types of craving. The aim of this study was to assess the effect of systematic virtual reality cue exposure treatment (VR-CET) on background and cue-induced cravings.

Methods: Participants were 48 treatment-seeking smokers. The VR-CET consisted of prolonged exposure sessions to several interactive virtual environments. The VR-CET was applied once a week over 5 weeks. An individualized hierarchy of exposure was drawn up for each patient starting from the easiest virtual environment. Background and cue-induced cravings were recorded in each session.

Results: Cue-induced craving decreased over each session as a result of prolonged exposure. VR-CET also reduced cue-induced and background cravings across the 5 sessions, showing a cumulative effect across the exposure sessions.

Conclusions: Our results evidenced the utility of VR-CET in reducing both types of cigarette craving. A combination of CET through VR with psychological treatments may improve current treatments for smoking cessation.

INTRODUCTION

Cigarette smoking remains one of the highest public health priorities and the leading preventable cause of premature death worldwide. According to the [World Health Organization \(2012\)](#), tobacco consumption kills nearly 6 million people each year.

Cigarette craving has been associated with the maintenance of smoking behavior ([Bagot, Heishman, & Moolchan, 2007](#); [Drummond, 2001](#); [Shiffman et al., 1997](#)), with lower rates of success for trying to quit ([Baker et al., 2011](#)), and with a greater likelihood of relapse after smoking cessation ([Berlin, Singleton, & Heishman, 2013](#); [Killen & Fortmann, 1997](#); [Piasecki, 2006](#); [Strong et al., 2011](#)).

Two categories of craving have been identified: background or tonic craving, and cue-induced craving or episodic craving ([Ferguson & Shiffman, 2009](#); [Sayette et al., 2000](#)). Background craving is defined as a relatively steady experience of craving over time ([Piasecki, 2006](#)). This type of craving is related to dependence severity and specifically to the presence of

withdrawal symptoms ([Brandon et al., 2011](#); [Schuh & Stitzer, 1995](#)). Background craving increases as a function of smoking deprivation but tends to decrease after smoking cessation ([Payne, Smith, Sturges, & Holleran, 1996](#); [Piasecki et al., 2000](#)). Cue-induced craving involves phases of acute spikes of craving that are typically triggered by external or internal cues associated with smoking ([Ferguson & Shiffman, 2009](#); [Sayette et al., 2000](#)). Cue-induced craving appears to be difficult to reduce and persists after smoking cessation ([Bedi et al., 2011](#); [Gass, Wray, Hawk, Mahoney, & Tiffany, 2012](#)).

Because both types of craving contribute to the maintenance of smoking behavior and precipitate relapse after quitting ([O'Connell, Shiffman, & DeCarlo, 2011](#)), targeted interventions that reduce craving need to be applied during smoking cessation procedures ([Bedi et al., 2011](#); [Shiffman, 2009](#)). Cue exposure treatment (CET) involves repeated exposure to cues that provoke craving in order to extinguish the urge to smoke ([Carter & Tiffany, 1999](#); [Conklin & Tiffany, 2002](#); [Unrod et al., 2014](#)). Virtual reality (VR) has shown many advantages over traditional techniques of exposure ([Baumann & Sayette,](#)

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2006; Bordnick, Yoon, Kaganoff, & Carter, 2013; Kaganoff, Bordnick, & Carter, 2012; Martin, LaRowe, & Malcolm, 2010), but few studies have used cue exposure through VR (VR-CET) in the context of smoking cessation treatments (Choi et al., 2011; Culbertson, Shulenberg, De La Garza, Newton, & Brody, 2012; Girard, Turcotte, Bouchard, & Girard, 2009; Moon & Lee, 2009). As a result, several important questions remain unanswered.

Firstly, previous studies about the utility of VR-CET in reducing cue-induced craving have shown mixed results. While some studies found a significant reduction in cue-induced craving (Choi et al., 2011; Culbertson et al., 2012), other studies did not report a decrease after the exposure procedures (Lee et al., 2004; Moon & Lee, 2009).

Secondly, despite the relationship between background craving and cue-induced craving in CET studies (Carter et al., 2009; Tiffany, Cox, & Elash, 2000), no investigation to date has assessed the effect of VR-CET on background craving (Choi et al., 2011; Culbertson et al., 2012).

Thirdly, previous studies may have used exposure sessions too short in duration (e.g., 10 min) (Choi et al., 2011; Culbertson et al., 2012; Yoon et al., 2013), which could have prevented achieving significant cue-induced craving reductions. Basic animal and human research has demonstrated that longer presentations of stimuli are more effective in the completion of extinction processes (Craske & Mystkowski, 2006; Sue, 1975).

Fourthly, even though cue-induced craving can be found in a number of everyday situations and is therefore quite a generalized response (García-Rodríguez et al., 2011; Thewissen, Snijders, Havermans, van den Hout, & Jansen, 2006), most studies have used only one or two virtual environments (Choi et al., 2011; Lee et al., 2004; Yoon et al., 2013). In order to avoid a renewal effect and facilitate the generalization of extinction responses, smokers should be exposed to a broader variety of environments reproducing high-risk situations during VR-CET.

We sought to address these gaps in knowledge by conducting a well-controlled experimental study. The specific goal of the present study is to assess the effect of a systematic VR-CET on background and cue-induced craving among treatment-seeking smokers.

METHODS

Participants

Participants were treatment-seeking smokers recruited via flyers and advertisements posted around the local community in two different cities of Spain, Oviedo and Barcelona. Inclusion criteria for the study were to be aged more than 18; to meet the diagnostic criteria for nicotine dependence according to the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; *DSM-IV-TR*) (American Psychiatric Association, 2000) assessed using the Structured Clinical Interview for *DSM-IV*; and to smoke 10 or more cigarettes per day for at least 1 year. Participants were excluded if they were diagnosed with a current severe psychiatric disorder (dementia or a psychotic disorder), if they met criteria for abuse or dependence on a substance other than nicotine, or if they were currently involved in other smoking cessation treatment. The final sample was made

up of 48 smokers (14 men and 34 women). The sociodemographic and clinical characteristics of the sample are shown in Table 1.

Instruments

During the intake session, participants filled out a clinical history form to provide data on sociodemographic and smoking-related characteristics. The Fagerström Test for Nicotine Dependence (Heatherton, Kozlowski, Frecker, & Fagerström, 1991) was used to assess nicotine dependence in addition to the *DSM-IV-TR* criteria. Carbon monoxide (CO) concentrations in expired air were measured in parts per million with a Micro Smokerlyzer (Bedfont Scientific Limited).

Participants also completed the Presence Questionnaire (Slater, Steed, McCarthy, & Maringelli, 1998) to rate the degree to which they had experienced the sense of being in the virtual environment, to what extent the virtual environment was the dominant reality, and to what extent it was recalled as a real place.

The VR system consisted of a standard laptop installed with a Microsoft Windows XP operating system, and eyewear Vuzix iWear VR920 (Vuzix) with a head tracker with 3 *df* that allowed participants to change the orientation of the viewpoints with their head movements. Participants freely moved through the environments and interacted with executable objects with a standard mouse device. The virtual environments used for VR-CET consisted of seven realistic situations with proximal, distal, and complex cues based on a previous study of contexts and cues related to smoking craving (García-Rodríguez et al., 2011). The virtual situations (distal cues) were as follows: *being in a pub, having lunch at home, having breakfast at home, having coffee at a cafe, having lunch at a restaurant, waiting in the street, and watching TV at night*. The smoking paraphernalia (proximal cues) included packs of cigarettes of several brands, ashtrays, burning cigarettes, cigarette vending machines, alcoholic beverages, and coffee. The complex cues were situations involving social interactions where people were smoking or offering cigarettes, talking, dancing, having coffee, and drinking alcoholic beverages. These environments were previously validated to produce craving in cigarette smokers, and a more detailed description of each one has been documented in previous studies (García-Rodríguez, Pericot-Valverde, Gutiérrez-Maldonado, Ferrer-García, & Secades-Villa, 2012). Several screen captures of the virtual environments are shown in Figure 1.

Table 1. Sociodemographic and Clinical Characteristics (*N* = 48)

	Mean $\pm$ SD/%
Age (years)	39.46 $\pm$ 12.9
Sex (% female)	70.8
Years of regular smoking	20.3 $\pm$ 10.6
Cigarettes per day	18.2 $\pm$ 7.7
FTND	4.8 $\pm$ 2.3
CO level (ppm)	13.2 $\pm$ 6.1
Presence questionnaire	19.5 $\pm$ 9

Note. CO = carbon monoxide; FTND = Fagerström Test for Nicotine Dependence; ppm = parts per million.

Figure 1. Screen captures of the virtual environments.

Craving responses (background and cue-induced) were recorded on a Visual Analog Scale (VAS) from 0 to 100. Smokers rated from not at all (0) to extremely (100) their level of craving by answering the question, “How strong is your desire to smoke a cigarette right now?” Background craving was recorded at the beginning of each session and prior to the virtual exposure using a VAS over a black screen. Cue-induced craving was assessed with a VAS built into the virtual environments every 2 min during each exposure. Two values of cue-induced craving were used for the present study, the highest value during the first 6 min of exposure and the final value at the end of each exposure session. The selection of the highest cue-induced value during the first 6 min was based on a previous study analyzing patterns of reactivity during VR exposure (Pericot-Valverde, García-Rodríguez, Gutiérrez-Maldonado, Ferrer-García, & Secades-Villa, 2011).

Procedure

During the intake session, participants were trained in the use of the VR system. The testing environment consisted of a room where some instructions were presented in order to maximize interaction with the objects and avatars during the exposure sessions and to provide familiarity with the craving assessment scale.

Participants were asked to rate from 0 to 10 the extent to which each of the eight potential situations would trigger a desire to smoke, and the five that produced the highest rates were selected for exposure sessions. An individualized hierarchy of exposure was drawn up for each patient starting with the situation that produced the least desire to smoke, increasing the level of challenge in each subsequent session.

The VR-CET intervention was applied once a week over 5 weeks. The exposure session had a maximum duration of 30 min and all five sessions followed the same protocol. No instructions to abstain immediately before each session were given to the participants, who were then considered to be nondeprived smokers. Participants were seated within a comfortable room without light or sound. The therapist put the eye-wear on the patient's head and described the virtual situation. Then, patients were encouraged to observe and interact with the virtual situation and the exposure started. To ensure that participants were actively involved in the virtual environment exposure, the therapist in charge watched participants' movements and craving ratings. Exposure was finished when cue-induced craving dropped to background levels for that session, or to background levels + 15% when the exposure had exceeded 20 min. After each exposure session, expired CO levels and the number of cigarettes smoked per day during the previous week were collected. Then, participants were encouraged to gradually reduce their nicotine intake during the coming week. Sample collection and advice were provided in a group-based format of four to five people immediately after the last individual exposure finished. Participants were not allowed to leave the laboratory to smoke despite the length of their exposure.

Data Analysis

Frequency and descriptive analyses were performed with sociodemographic and clinical characteristics. To determine the effect of the VR-CET on cue-induced craving, paired sample *t* tests were conducted to compare the highest value and final value at each treatment session.

Changes across treatment sessions in each of the three measures of craving (background craving, highest value of cue-induced craving, and final value of cue-induced craving) and smoking behavior (number of cigarettes per day and CO levels) were assessed using repeated-measures analyses of variance. Eta-squared (η^2) values were computed as estimates of effect sizes for all comparisons. According to the guidelines proposed by Cohen (1988), effect sizes were considered as “small, $\eta^2 = 0.01$,” “moderate, $\eta^2 = 0.06$,” and “large, $\eta^2 = 0.14$.” Data were analyzed with the statistical package SPSS for Windows (version 15, SPSS Inc.).

RESULTS

Table 2 shows the difference between the highest value and final value of cue-induced craving during VR-CET. Cue-induced craving significantly decreased in each exposure session, with very large effect sizes ranging between 0.41 and 0.67.

Background craving decreased significantly across the five VR-CET sessions ($F_{(44, 160)} = 9.75, p < .001$, partial $\eta^2 = 0.72$). Background craving before the virtual exposure sessions was significantly higher than in the last virtual exposure session. Effect size for this variable was large (Figure 2).

The highest value of cue-induced craving declined significantly over exposure sessions ($F_{(44, 160)} = 7.935, p < .001$, partial $\eta^2 = 0.68$). The magnitude of the difference was also large. The final value of cue-induced craving decreased significantly after the five virtual exposure sessions ($F_{(44, 160)} = 7.188, p < .001$, partial $\eta^2 = 0.66$). Effect size was also large.

Cigarettes smoked per day ($F_{(4, 36)} = 41.144, p < .001$, partial $\eta^2 = 0.82$) and CO in expired air ($F_{(4, 39)} = 9.554, p < .001$, partial $\eta^2 = 0.49$) decreased significantly across exposure sessions with large effect sizes (Figure 3).

DISCUSSION

The main purpose of this study was to assess the effect of VR-CET on background and cue-induced craving in treatment-seeking smokers. We highlight two major findings: (a) cue-induced craving was significantly reduced during each of the virtual cue exposure sessions and (b) both cue-induced and background craving decreased gradually across the five virtual cue exposure sessions.

Contrary to previous reports (Choi et al., 2011; Lee et al., 2004; Moon & Lee, 2009), the VR-CET was able to reduce cue-induced craving at each treatment session. The short length of the exposure sessions used in previous studies may

contribute to explaining this discrepancy. While in the current study the length of VR-CET sessions ranged between 8 and 20 min, previous research was based on cue exposure sessions that ranged between 30 s and 11 min (Choi et al., 2011; Culbertson et al., 2012). Our results show that the duration of the exposure to conditioned stimuli appears to be a critical component in the process of extinction. Thus, extending the duration of exposure to smoking-related cues may contribute to decreasing cue-induced craving in smokers. In addition, this study used 1-week intervals between each VR-CET session. Animal recovery research has demonstrated that spaced extinction trials produce more effective results than massed extinction trials (Urcelay, Wheeler, & Miller, 2009). Providing time between sessions allows spontaneous recovery to occur where responses to extinguished stimuli are required, providing an additional training (Conklin & Tiffany, 2002). Despite longer intervals between sessions leading to an increase in treatment duration, these responses remain extinguished (Conklin & Tiffany, 2002; Mackintosh, 1974). Our results are consistent with the assumption that long intervals between repeated exposures of VR-CET may have facilitated extinction and therefore could prevent recovery of extinguished responses.

Our results demonstrate that VR-CET effectively reduced cue-induced craving across the 5 weeks of virtual cue exposure sessions, a finding only recently reported in a study using regular CET (Unrod et al., 2014). Previous VR-CET research only reported modest decreases in cue-induced craving over cue exposure sessions (Choi et al., 2011; Culbertson et al., 2012). In our study, cue exposure repeated over several sessions may have produced a cumulative effect during treatment, which would enhance the reduction of cue-induced craving at the end of treatment. One mechanism that can explain this cumulative effect could be the habituation to smoking-related cues, so that within-session extinction facilitated the occurrence of between-session habituation. Moreover, cue-induced craving levels decreased on completion of the VR-CET despite the difficulty of virtual environments increasing progressively through exposure sessions. The extinction of cue-induced craving in a virtual environment may have facilitated the generalization of extinction to other virtual environments (García-Rodríguez et al., 2011; Havermans & Jansen, 2003).

Our results also support previous findings documenting that background craving can be effectively attenuated. However, most studies that found these results used pharmacological treatments (Burton & Tiffany, 1997; Carter et al., 2009; Hitsman et al., 2013; Tiffany et al., 2000). In this study, VR-CET reduced background craving across exposure sessions, a finding not previously reported. Some authors have suggested that there is a mutual influence of one type of craving over the other when both are assessed (Carter et al., 2009;

Table 2. Comparisons Between Highest Value and Final Value of Cue-Induced Craving During Each Exposure Session

Sessions	Highest value of cue-induced craving (0–100) ($M \pm SD$)	Final value of cue-induced craving (0–100) ($M \pm SD$)	<i>t</i>	<i>p</i> value	η^2
1	45.83 $\pm$ 29.16	19.52 $\pm$ 23.62	7.23	.000	0.526
2	37.27 $\pm$ 22.37	14.59 $\pm$ 19.48	8.45	.000	0.608
3	28.11 $\pm$ 23.37	10.95 $\pm$ 17.29	7.35	.000	0.562
4	22.30 $\pm$ 19.65	8.11 $\pm$ 13.35	6.61	.000	0.675
5	18.02 $\pm$ 18.73	6.78 $\pm$ 12.05	5.38	.000	0.419

Figure 2. Background craving across treatment sessions.

Figure 3. Number of cigarettes per day and exhaled carbon monoxide (CO) across treatment sessions.

Tiffany et al., 2000). For example, high values of background craving can increase the salience of smoking-related cues and thus amplify cue-induced craving effects (McClernon, Kozink, Lutz, & Rose, 2009). On the other hand, high values of background craving can result in ceiling effects that make it difficult to distinguish between background and cue-induced cravings (Sayette & Tiffany, 2013). In the current study, the highest levels of cue-induced craving during the exposure were not extremely high, suggesting that the effects of the virtual environments to enhance cue-induced craving over background or tonic craving were moderate. However, absolute values of cue-induced craving are consistent with previous studies on cue reactivity in smokers, which also found values in the middle range of the scale (Bordnick et al., 2013; Conklin, Robin, Perkins, Salkeld, & McClernon, 2008; García-Rodríguez et al., 2012; García-Rodríguez, Weidberg, Gutiérrez-Maldonado,

& Secades-Villa, 2013; Lee et al., 2003; Traylor, Bordnick, & Carter, 2008), including the validation study of the virtual environments used here for VR-CET (García-Rodríguez et al., 2012). Participants in the validation study showed similar cue-induced craving levels but reported lower tonic values due to the satiation procedure prior to the exposure session, causing a greater increase in craving values as a result of the exposure. Despite no acute deprivation before each session being asked for in the current study, background craving in these subjects appears to also be higher than in previous studies featuring regular smokers (Bordnick et al., 2004; Carter et al., 2006; Paris et al., 2011; Tong, Bovbjerg, & Erblich, 2007) leading to the relatively small difference between background craving and the highest level of cue-induced craving at each session. This might be due to several reasons: differences in preexposure procedures (satiation vs. deprivation), a differential pattern of

craving responses in treatment-seeking smokers versus those not seeking treatment (Bordnick et al., 2013), but also to the reduction of nicotine intake that may then be increasing tonic or background craving (Bailey, Goedeker, & Tiffany, 2010; Carter et al., 2006) to similar levels of cue-induced craving (Traylor, Parrish, Copp, & Bordnick, 2011).

Our results support the relationship between both types of craving during VR-CET. The role of VR-CET in reducing the levels of background craving might prevent the risk of relapse after quitting. Therefore, this study suggests that VR-CET should include assessment of both background craving and cue-induced craving. Moreover, this study showed an effect of the VR-CET on smoking behavior. Smokers significantly reduced the number of cigarettes smoked per day and these reductions were corroborated by levels of CO in expired breath. Our results are consistent with previous studies that reported a reduction in both craving and daily nicotine intake after VR-CET (Choi et al., 2011; Culbertson et al., 2012) and also that the decline in craving may be related to reductions in tobacco use (Pericot-Valverde et al., 2013).

Limitations in our study should be mentioned. Firstly, the relatively small sample size and the lack of a control exposure condition make it difficult to apply the generalization of the present results to other treatment-seeking smokers. Secondly, the absence of follow-ups after the five sessions prevents obtaining knowledge of the long-term effect of VR-CET on craving levels or smoking. Thirdly, we did not measure physiological indices related to craving, such as heart rate or skin conductance, which would allow comparisons between the subjective scores and objective measurements. Fourthly, a common limitation among nonbasic research CET studies is that complete control of potentially confounding effects of exposure to smoking-related cues in real life between exposure sessions is not possible. Over the course of the treatment, participants may be exposed to specific contexts or persons related to tobacco use without the control of the research team. Similarly, physiological feedback and social support given after each session may lead to confounding effects in both craving and actual smoking reductions. Lastly, cue-induced craving levels were not much higher than background craving levels across sessions reflecting a modest effect of craving manipulation.

Despite these limitations, we found that prolonged VR-CET led to reduced cue-induced craving during each treatment session, reduced background and cue-induced craving between sessions in treatment-seeking smokers, and also facilitated smoking reductions. Future studies should assess whether the combination of effective psychological treatments with CET through VR could improve treatments for smoking cessation.

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DECLARATIONS OF INTERESTS

None declared.

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