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BRIEF REPORT

(No) escape from reality? Cigarette craving in virtual smoking environments

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Abstract Cue-Exposure Therapy (CET) is considered an effective strategy to combat cigarette cravings and smoking relapses, but evidence is mixed. In this lab-based experimental study, we manipulated levels of realism for smoking scenarios in Virtual Environments (VE) and randomly exposed smokers and recent-quitters to one of two versions (low versus high realism) of these scenarios. Prior and after scenario exposure, valid measures of cigarette craving were obtained. Prior to exposure, we assessed nicotine dependence and smoking status (current smokers versus recent-quitter). Within-subject repeated measures analysis of covariance showed that there was an interaction of experimental condition with smoking status on cigarette craving. Amongst recent-quitters, high realistic scenarios produced stronger increases in craving than low realistic scenarios, but this effect was reversed in current smokers. It is concluded that VE technologies are a potentially relevant tool for smoking CET that warrant further exploration.

Keywords Virtual reality · Cue exposure · Smoking · Craving · Experiment

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Smoking continues to be a leading cause of noncommunicable mortality and morbidity in large parts of the world. Even though a large proportion of the smoking populace make quit attempts, a large proportion of those attempts result in a smoking relapse (Hughes et al., 2004). A key predictor of smoking relapse is cigarette craving, where one has an intense desire for an object or experience after exposure to craving-related cues or stimuli (Carter & Tiffany, 1999). Meta-analytical evidence indicates a strong relationship between cue exposure and cigarette cravings (Karelitz, 2019). Cue exposure therapy (CET) is considered to be an effective tool to combat these cravings and high relapse rates. In CET, participants are presented with cues that induce craving, but are refrained from enacting the learned behavioral response (Martin et al., 2010). Yet, summary studies have not found consistent support that CET promotes (long-term) smoking cessation (Park et al., 2014) nor cigarette craving (Pericot-Valverde et al., 2015). One of the main reasons for this inconsistent evidence is that current CET tends to present very proximal craving cues, such as a close-by friend smoking or lighting a cigarette, or cigarette trays placed on a bar or table. However, the distal background in which these proximal cues reside, such as the broader physical or social context, is known to produce learning effects on behavioral responding, even when proximal cues are absent (Conklin, 2006). This is problematic for traditional CET strategies, because their modalities cannot completely accommodate these broader distal contexts (García-Rodríguez et al., 2011).

One way to overcome this limitation is to use Virtual Environments (VE) in CET, where people are transported from the real environment to a technology-based VE. In VE, real-life situations and responses are mimicked through (tele) presence. Real-life differences in cigarette craving between neutral and smoking cues can not only be replicated in VE

(Baumann & Sayette, 2006), but smoking cues in VE produce stronger cravings than when these cues are presented in more static pictorial modalities (Lee et al., 2003). Immersion is a key concept in VE, defined as the extent to which hardware and technologies present a perception of reality to human senses (Slater, 2018), such as through high-quality graphics, natural movement, or haptic feedback. Although high levels of immersion should lead to VE responses that closely mimic real-life responses, very little experimental research has been done to investigate this issue in behavioral change regarding health. The purpose of this study was to manipulate immersion and assess the effects of high-immersive VE (versus low-immersive) on within-subject changes in cigarette cravings. We hypothesized that high-immersive VE would lead to stronger changes than less-immersive (H1). Because recent abstinence may increase cravings after exposure to smoking cues (Tiffany et al., 2009), we hypothesized an interaction between smoking status and level of immersion (H2), with the strongest increases in cravings in recent-quitters exposed to a high-immersive VE (H3).

Method

Participants and procedures

Ninety-one participants ($M_{age} = 21.21$, $SD = 3.81$; 70.2% female ($n = 64$)) registered as study participants after reading the leaflet that informed them of the study inclusion and exclusion criteria, but that masked the study purpose. Inclusion criteria were adult age and being either a current smoker, or having (a) quit (attempt) in the past three months. Study completion took around 25 min and standard reward fee (i.e. one course credit or 5 euro) was applicable. Upon registration, a participant was randomized into one of the two experimental conditions and allocated a lab visit time slot. There, participants read the detailed information leaflet about the study procedures (again masking the purpose) and requested to sign the informed consent form. Participants completed the baseline survey online and were subsequently aided for the VE procedure by the lab assistant, who told them they would be viewing and rating a 360-degrees movie with three specific smoking situations. After movie completion, participants completed the follow-up online survey and debriefed, paid and thanked.

Measures

Smoking status was assessed with a single item asking participants whether or not they were current smoker (yes versus no). *Smoking behavior* was assessed by two questions. The first asked participants to indicate if they had smoked in the previous six months in three smoking situations (yes versus no), previously identified to produce strong cigarette craving effects, namely (1) being in a pub, (2) waiting in the street on public transport to arrive, and (3) in the morning, just after having breakfast (García-Rodríguez et al., 2012; Lee et al., 2003; Baumann & Sayette, 2006). Participants who answered 'yes' to the first question were further queried about the frequency (1 = never, 5 = always) with which they smoked in those situations. *Cigarette craving* was assessed using two separate instruments. The first asked participants to indicate their present cigarette craving on a Visual Analogue Scale (VAS), ranging from 0 (no cravings whatsoever) to 100 (extreme cravings). The second was the Short Form Tobacco Craving Questionnaire (SFTCQ) (Heishman et al., 2008). Reliability was good at both baseline and follow-up ($\alpha > 0.89$), and higher mean scores reflected stronger cigarette cravings. *Cigarette dependence* was also assessed, as cigarette craving is associated not only with cigarette dependence over and above the amount and duration of cigarettes smoked (Donny et al., 2008), but also impacts cigarette craving in VR (Thompson-Lake et al., 2015; Park et al., 2014). It was assessed with the Cigarette Dependence Scale (CDS)(Etter et al., 2003), and higher mean scores indicated a stronger dependence ($\alpha = 0.87$). A manipulation check was performed using a VAS—ranging from 0 (completely not immersed in the VE) to 100 (completely immersed in the VE)—and with the Igroup Presence Questionnaire (IPQ) (Regenbrecht & Schubert, 2002), given that strong feelings of presence are indicative of highly immersive VE (Slater, 2018).

Manipulations

Three situations have been identified in previous work to produce strong cigarette craving effects, namely (1) being in a pub, (2) waiting in the street on public transport to arrive, and (3) in the morning, just after having breakfast (García-Rodríguez et al., 2012; Lee et al., 2003; Baumann & Sayette, 2006). These situations were each filmed using an Insta 360 Pro VR Camera. In the first two situations, two young adult males were socializing while smoking a cigarette. In the other scene, one young male adult was standing alone on a balcony of an apartment, drinking coffee and smoking a cigarette. The Pro VR camera was set up to record each scene in a 4 K resolution, running at 60 frames per second and a 40 Mbps bit rate. The resulting movie was then formatted in a final version with 2560 × 1440 resolution. Stock sound effects were added that matched the environments of those situations. Each situation lasted 2:30 min, and each had a five-second fade-in and fade-out. Participants in the *low-immersive* condition viewed the final version of the movie on a OnePlus One smartphone with a 5.5" full HD display. They could look around in the 360-degrees environment by

tilting and turning the smartphone, and separate earphones were used for audio. Participants in the *high-immersive* condition viewed the same movie on the same smartphone, but now the smartphone was plugged into a BOBO VR Z5 Virtual Reality (VR) headset, that allowed participants to look around in the 360-degrees environment by turning and tilting their heads. This mimicked natural movement, indicative of high immersion. Participants listened to the audio content of the movies through the built-in HiFi surround earphones in the BOBO VR headset. Prior to movie exposure, the VR headset was customized to accommodate optimal hearing and viewing angles for each participant, using the built-in diopter adjustment system and pupillary distance. For both conditions, a one-minute neutral video was shown prior to exposure to allow participants to become accustomed with the technology.

Statistical analyses

The randomization check checked for differences in baseline variables across the conditions. These were assessed using the χ^2-test for gender, smoking status, and whether or not they had smoked in the three smoking situations. For age, nicotine dependence and cigarette craving, a one-way MANOVA was used. We also checked if there were differences across the two experimental groups, stratified per smoking status. We used the χ^2-test for categorical variables (gender, smoking status, smoking in situations) and a 2 (condition) × 2 (smoking status) MANOVA for age, cigarette craving and nicotine dependence. The manipulation check on immersion and presence scores was performed using a 2 (level of immersion: low versus high) × 2 (smoking status: current smoker versus recent quitter) MANOVA. The effects of experimental condition and smoking status on changes in cigarette craving were studied using a 2 (level of immersion: low versus high) × 2 (smoking status: current smoker versus recent-quitter) repeated measures ANCOVA, with craving at baseline and at immediate follow-up as the within-subject factor. Two separate ANCOVAs were run for each of the craving outcome measures. For both ANCOVAs, nicotine dependence was used as covariate. Significant main and interaction effects were followed up by planned comparisons. The effect sizes partial η^2 and Cohen's d (Cohen, 1992) were used to assess the relevance of the mean differences, next to their statistical significance. Cohen's d was calculated with suggested formulas for means and standard errors (Wilson & Lipsey, 2001). Power analysis using G*Power (Faul et al., 2007) for a 2 × 2 repeated measures ANOVA with $\alpha = 0.05$ and $\beta = 0.95$ indicated that 72 participants would be needed to detect a small-to-medium effect size difference in craving, with correlations for repeated measures set at 0.70. This effect size is smaller than a recently identified effect size for craving after cue exposure (Karelitz, 2019).

Results

Baseline descriptives

Three participants were excluded, because they reported to have smoked less than one cigarette per day in the past six months. The final analyzed sample therefore consisted of 88 participants. Table 1 has the descriptives across the two experimental conditions, specified per smoking status. No differences across these four groups were found for gender, nor for whether or not participants had previously smoked in the each of the three situations, all $ps > 0.58$. There was no multivariate effect of condition, nor an interaction with smoking status, both $ps > 0.098$, but there was an effect of smoking status, F (4, 81) = 21.02, $p < 0.001$, related to cigarette dependence, F (1, 84) = 76.05, $p < 0.001$. Smokers reported higher cigarette dependence ($M = 2.92$, $SD = 0.69$) than recent-quitters ($M = 1.40$, $SD = 0.89$). Therefore, cigarette dependence was entered as a covariate for the hypothesis tests.

Manipulation and randomization check and hypothesis testing

There were no differences in baseline variables between conditions (all $ps > 0.591$), so randomization was successful. The manipulation check revealed a significant multivariate effect of condition, F (2, 83) = 4.96, $p = 0.009$, Wilks' $\lambda = 0.91$, partial $\eta^2 = 0.10$, but no significant effects of smoking status nor the interaction of condition with smoking status (both $Fs < 1$). Participants in the high-immersive condition had higher scores on immersion ($M = 63.16$, $SD = 18.48$) and presence ($M = 0.85$, $SD = 0.92$) than participants in the low-immersive condition (Immersion: $M = 50.39$, $SD = 22.21$; Presence: $M = 0.31$, $SD = 1.01$), so manipulation was successful.

Regarding hypothesis 1, there was no effect of time, F (1, 83) = 2.77, $p = 0.100$, Wilks' $\lambda = 0.97$, partial $\eta^2 = 0.03$, nor an interaction with condition for the SFTCQ scores, $F < 1$. For VAS, there was also no effect of time, F (1, 83) = 3.07, $p = 0.083$, Wilks' $\lambda = 0.96$, partial $\eta^2 = 0.04$, nor an interaction of time with condition, $F < 1$. Therefore, hypothesis 1 was rejected. There was no effect of baseline cigarette dependence on the craving measures (both $Fs < 1$). Regarding hypothesis 2, there was no interaction of time, smoking status and condition, F (1, 83) = 3.20, $p = 0.077$, Wilks' $\lambda = 0.96$, partial $\eta^2 = 0.04$, for the SFTCQ scores. For VAS, there was a significant interaction between time, condition and smoking status, F (1, 83) = 10.62, $p = 0.002$, Wilks' $\lambda = 0.89$, partial $\eta^2 = 0.11$, confirming H2.

Amongst smokers, craving increased substantially more in the low-immersive condition (baseline: $M = 26.68$, $SE = 4.66$; follow-up: $M = 52.97$, $SE = 5.19$; Cohen's

Table 1 Means and Standard Deviations, and Distributions of Study Variables in Analyzed Sample ($n = 88$)

		Smoker Immersion	Recent-quitter	Smoker Immersion	Recent-quitter
		Low	Low	High	High
Baseline	n = 88	n = 27	n = 14	n = 31	n = 16
% female (*n*)	70.5% (62)	74.1% (20)	64.3% (9)	74.2% (23)	62.5% (10)
Age	21.2 (3.8)	20.7 (2.6)	23.1 (7.2)	20.9 (3.0)	20.8 (2.5)
Tobacco Craving VAS	28.7 (22.9)	31.6 (24.4)	19.6 (19.0)	29.8 (24.1)	29.7 (21.4)
Tobacco Craving SF-TCQ	−0.8 (1.1)	−0.6 (1.0)	−1.6 (1.0)	−0.8 (1.1)	−0.6 (1.0)
Nicotine Dependence	2.4 (1.1)	3.0 (0.6)	1.5 (1.2)	2.9 (0.8)	1.3 (0.6)
% (n) smoked public transport	85.2% (75)	96.3% (26)	64.3% (9)	90.3% (28)	75.0% (12)
% (n) smoked coffee in the morning	58.0% (51)	70.4% (19)	42.9% (6)	58.1% (18)	50% (8)
% (n) smoked terrace at a pub	100% (88)	100% (27)	100% (14)	100% (31)	100% (16)
Smoking frequency—public transport	1.8 (1.0)	2.3 (1.0)	1.2 (0.7)	1.7 (0.9)	1.6 (1.0)
Smoking frequency—coffee in the morning	2.1 (1.2)	2.3 (1.3)	1.2 (0.4)	2.2 (1.2)	2.4 (1.3)
Smoking frequency—terrace at a pub	2.8 (1.1)	3.2 (0.8)	1.8 (0.9)	2.9 (1.1)	2.9 (0.9)
Follow-up					
Tobacco Craving VAS	44.6 (28.1)	59.0 (24.5)	22.0 (23.9)	42.4 (26.9)	44.2 (27.3)
Tobacco Craving SF-TCQ	−0.4 (1.3)	0.1 (1.1)	−1.3 (1.5)	−0.5 (1.3)	−0.2 (1.2)
Immersion (VAS)—average of situations	57.2 (21.2)	51.5 (19.2)	45.7 (30.1)	62.9 (18.6)	63.6 (18.8)
Immersion (VAS)—public transport	51.9 (25.2)	47.5 (26.5)	51.7 (31.4)	55.2 (22.3)	58.2 (23.0)
Immersion (VAS)—coffee in the morning	57.9 (26.6)	49.8 (25.5)	47.1 (30.2)	63.7 (22.3)	65.8 (28.9)
Immersion (VAS)—terrace at a pub	61.8 (24.6)	57.3 (23.2)	48.2 (27.9)	70.0 (20.1)	66.9 (24.2)
Presence (IPQ)	0.6 (1.0)	0.3 (1.0)	0.4 (1.1)	0.8 (1.0)	1.0 (0.8)

SF-TCQ = Short Form Tobacco Craving Questionnaire. VAS = Visual Analogue Scale. IPQ = International Presence Questionnaire. SF-TCQ could range from −3 (no craving at all) to +3 (extreme cravings), and Nicotine Dependence from 1 (no dependence) to 5 (extreme dependence). Frequency at situation was assessed only in those reporting 'Yes' to that specific situation and could range from 1 (never) to 5 (always). Immersion could range from 0 (completely not immersed) to 100 (completely immersed) and scores on IPQ could range from −3 (completely no feelings of presence) to +3 (complete feelings of presence)

d = 1.05, 95% CI [0.47–1.63]) than in the high-immersive condition (baseline: $M = 25.99$, $SE = 4.23$; follow-up: $M = 37.84$, $SE = 4.72$; Cohen's d = 0.48, 95% CI [−0.02 to 0.99]). In contrast, amongst recent-quitters, changes in craving were less substantial between the low-immersive condition (baseline: $M = 27.11$, $SE = 6.57$; follow-up: $M = 31.11$, $SE = 7.32$; Cohen's d = 0.16, 95% CI [−0.58 to 0.90]) as compared to the high-immersive condition (baseline: $M = 38.79$, $SE = 6.51$; follow-up: $M = 55.19$, $SE = 7.26$; Cohen's d = 0.61, 95% CI [−0.10 to 1.33]). The most pronounced craving changes were found in current smokers exposed to low-immersive scenarios, rejecting H3.

Discussion

Results showed that there no main effect of immersion on craving. This is unexpected, because immersion and subsequent feelings of presence are considered to be key mechanisms for inducing real-life physiological, emotional, cognitive, and behavioral responses in virtual environments (Slater, 2018). Although there is consistent evidence that technological manipulations of immersion enhance feelings of presence (Wu et al., 2018), there is much less consistent evidence that enhanced presence initiates changes in performance (Lackey et al., 2016) and exposure therapy effects (Ling et al., 2014). Although tentative, when situations that are less complex, easier to understand, and relatively frequently encountered in real-life are modelled in VE, low immersive VE oftentimes perform as good as high immersive VE (Bowman & McMahan, 2007). This blends in with participants' reports that they had frequently encountered the selected VE scenarios in real life, with all study participants having smoking on a terrace of a pub, while 85% had smoked while waiting for public transport.

Results showed the hypothesized interaction for VAS scores. Amongst recent-quitters, the craving changes were more than five times larger in the high-immersive condition than in the low-immersive condition. However, in current smokers, these changes were more pronounced, particularly when current smokers were exposed to a low-immersive VE, where the largest craving increases were

found. This meant that H3 was rejected. The reasons for these unexpected findings are unclear, but it may be that the smokers in the sample still had high levels of nicotine in their blood as they might have been smoking just before the start of the experiment. This may have impaired craving induction by the experimental stimuli. Another tentative explanation may be that high-immersive VE, because of its rich and realistic nature, causes more distraction from the smoking cues than low-immersive VE. Importantly, research has also indicated that in highly distracting situations, people report *lower* cravings after cue exposure than in non-distracting situations (Van Dillen & Andrade, 2016). The reasoning behind this, is that paying even a minimum amount of attention to craving-inducing cues requires cognitive effort, and that high distracting situations take away the cognitive capacity to attend to these cues (Van Dillen et al., 2013), particularly for people who are sensitive to these cues (Van Dillen & Andrade, 2016) such as those being cigarette dependent. These unexpected findings point to interesting directions for future research on VE development that can reduce cigarette craving and smoking relapse.

There are a few limitations that need mentioning. First, a convenience sample of current smokers and recent-quitters was used, with cigarette dependence scores slightly above midscale for current smokers, and relatively low for recent-quitters. This is a limitation for generalization, as most studies on VE and cigarette craving have tended to focus either on clinical samples of highly cigarette-dependent smokers or on people who are interested in smoking cessation (Baumann & Sayette, 2006; Thompson-Lake et al., 2015). Second, craving measures were not followed up by smoking behavior, for instance immediate ad libitum cigarette smoking. As a result, it is unknown if the changes in craving also led to changes in smoking behavior. We also did not assess the time of consumption of the last cigarette before experimental manipulation. This is a potentially important addition to future work on VR and cigarette craving, because recent abstinence is a strong predictor of cigarette craving (Hughes et al., 2004) and may impact cigarette craving, independent of exposure to smoking cues in VE. Third, there were no opportunities to interact with objects in the virtual environment, which is known to impact immersion and feelings of presence as well through enhanced action realism (McMahan et al., 2012). Finally, the effects on craving changes were only found for the VAS and not for the Likert-scale based SFTCQ. Although this may indicate that VAS has more relevance for studies on VE and cigarette craving (Hone-Blanchet et al., 2014), other Likert scales have been used to assess cigarette craving and should be used in future studies on VE manipulations and cigarette craving.

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Compliance with ethical standards

Conflict of Interest Gert-Jan de Bruijn, Joost de Vries, Catherine Bolman, and Reinout Wiers declare that they have no conflict of interest.

Human and animal rights and Informed Consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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