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Smokers "Context Reactivity" in Virtual Domestic Environments

Giulia Benvegnù[a, b] Francesco Tommasi[b] Stefano Ferraro[b] Elettra Libener[b] Marzia Di Chio[b] Sandra Bosi[c] Thomas Zandonai[d] Cristiano Chiamulera[b]

[a]Department of General Psychology, University of Padua, Padua, Italy; [b]Department of Diagnostic and Public Health, Pharmacology Section, Neuropsychopharmacology Lab, University of Verona, Verona, Italy; [c]Italian League against Cancer (LILT), Reggio Emilia, Italy; [d]Department of Pharmacology, Paediatrics and Organic Chemistry, Miguel Hernández University of Elche, Alicante, Spain

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Smoking · Cue reactivity · Context · Craving · Virtual reality

Abstract
Introduction: Although the effects of proximal smoking cues have been widely studied in smokers, little is known on the features associated with background spatial context effect, that is, "context reactivity." The aim of this study was to investigate context reactivity exhibited by smokers in virtual cue-free domestic scenarios. ***Methods:*** Sixty-nine participants divided in 2 cohorts (33 smokers and 36 non-smokers) were exposed to a virtual reality session with 4 domestic room scenarios presented in a balanced order: bedroom, bathroom, kitchen, and living room. ***Results:*** We showed that (i) it is possible to elicit smoking craving in smokers in virtual reality, and (ii) these effects are room dependent and (iii) associated with a lower sense of presence; furthermore, (iv) smokers reported higher craving scores for alcohol and food in a room-dependent fashion compared to non-smokers. ***Conclusion:*** Our study provides an experimental paradigm for assessing context reactivity in smokers and suggests a potential use for the identification of non-pharmacological interventions as a co-adjuvant of smoking cessation treatment.

Introduction

Smoking cue reactivity is the reaction to an environment rich of stimuli that informs motivated behaviours [1, 2]. It is a complex phenomenon that could be triggered by proximal and contextual cues [3]. The former are discrete stimuli, such as a package of cigarettes or a lighter, that typically accompany tobacco smoking [3]. *Contextual* stimuli refer to the configuration of spatial features that form the environment where smoking occurs. Interestingly, exposure to smoking-associated context can elicit reactivity alone without the presence of proximal cues [3]. Based on this, we may define this cue-free response as "*context reactivity*."

The consequences of context reactivity have been reported in several human laboratory and ecological studies [3–11]. However, the difficulty to recreate in the lab the complexity of spatial configuration that triggers context reactivity urges for ecologically oriented models with better control and individualization of variables [3, 12]. A promising methodological approach is virtual reality, a technology that creates a state of immersion closer to the

Giulia Benvegnù and Francesco Tommasi have contributed equally.

karger@karger.com
www.karger.com/ear

Karger

Correspondence to:
Thomas Zandonai, tzandonai@umh.es

real situation and allows for controlled assessment of neuropsychological and behavioural responses [13]. Virtual reality has been already used in smoking research [13–16]. Baumann and Sayette [17] showed a significantly increased smoking urge in smokers when immersed in a virtual environment rich of smoking cues compared to neutral ones. However, participants reported that some apparently neutral contextual situations also elicited smoking urge. Paris et al. [18] highlighted the role of smoking context to induce craving with a well-controlled study with/without smoking cues. Furthermore, García-Rodríguez et al. [19] categorized virtual reality contextual situations that increased smoking craving, such as being in a pub, having coffee at a café, or having lunch at home. These studies investigated psychological and neurophysiological reactivity responses such as craving, galvanic skin reaction, and others. What was however missing was a description of participants' experience of the smoking context in terms of perceptual dimensions. We think that the access to perceptual responses may help to further characterize from a smoker-centred perspective the features of a spatial context and its potential value for context reactivity.

The aim of our study was to investigate context reactivity exhibited by smokers to indoor proximal cue-free spaces in virtual reality. We assessed the responsiveness to 4 virtual domestic rooms in tobacco smokers compared to non-smokers by using psychometric assessment for food, alcohol and smoking craving, mood changes (positive and negative), and perceptive measures such as familiarity, novelty, comfort, pleasantness, arousal, and sense of presence.

Color version available online

Fig. 1. Screenshots of the virtual reality environments.

Methods

General Design

Four domestic room virtual scenarios were presented in a balanced order to both smoking and non-smoking cohorts: bedroom (BED), bathroom (BAT), kitchen (KIT), and living room (LIV) (Fig. 1). These scenarios were chosen to represent a prototypic space with the minimal number of elements necessary to identify the room type without cues associated with alcohol, food, or smoke. Each scenario was matched with an auditory background, that is, environmental noises from a computer, radio, fridge, fan, or music.

Participants

Sixty-nine, both sexes, participants were recruited through online and paper advertisements. They were invited to read and then to sign an informed consent document, which proved the involvement in the study. The study was approved by the Ethics Committee for Clinical Trials, University Hospital Integrated Trust of Verona (Project No. 1334CESC; Protocol No. VR2-2017), and followed the principles of the Helsinki Declaration. Inclusion criteria in the smoking cohort were smoking at least 5 cigarettes a day for at least the past year, while in the non-smokers cohort was to "not to be a current smoker." Exclusion criteria were personal or familial positive clinical history of seizures, clinical history for cardiovascular diseases or major chronic diseases, current pregnancy, wearer of cardiac pacemaker or other metallic devices in the head-neck district, except piercings or braces, current therapy with psychiatric drugs, consumption of psychoactive drugs which would have interfered with the results of the study, and having a diagnosis of alcohol use disorder.

Virtual Reality Equipment

Oculus Rift is a virtual reality head-mounted display developed by Oculus VR (Menlo Park, CA, USA). The Rift is designed to provide a stereoscopic vision of a 360° VR environment. Thanks to its rotational and positional tracking system, Oculus Rift allows the participant to explore the scene by moving his own head and body. The virtual reality scenarios were implemented by using the Unity cross-platform game engine.

Questionnaires

The Fagerström Test for Nicotine Dependence [20] is a questionnaire to test the degree of nicotine dependence via tobacco smoking. The Smoking Status Assessment questionnaire consists of 5 questions about the current smoking status and the smoking history of smokers. We collected the following 11 item variables as VAS scales: items 1 and 2 measured *smoking* and *alcohol craving*, respectively (with a scale ranging from 0 to 9, adapted from Traylor et al. [21]); item 3 *food craving*; items 4 and 5 measured *positive* and *negative mood* changes [22]; items from 6 to 11 (adapted from

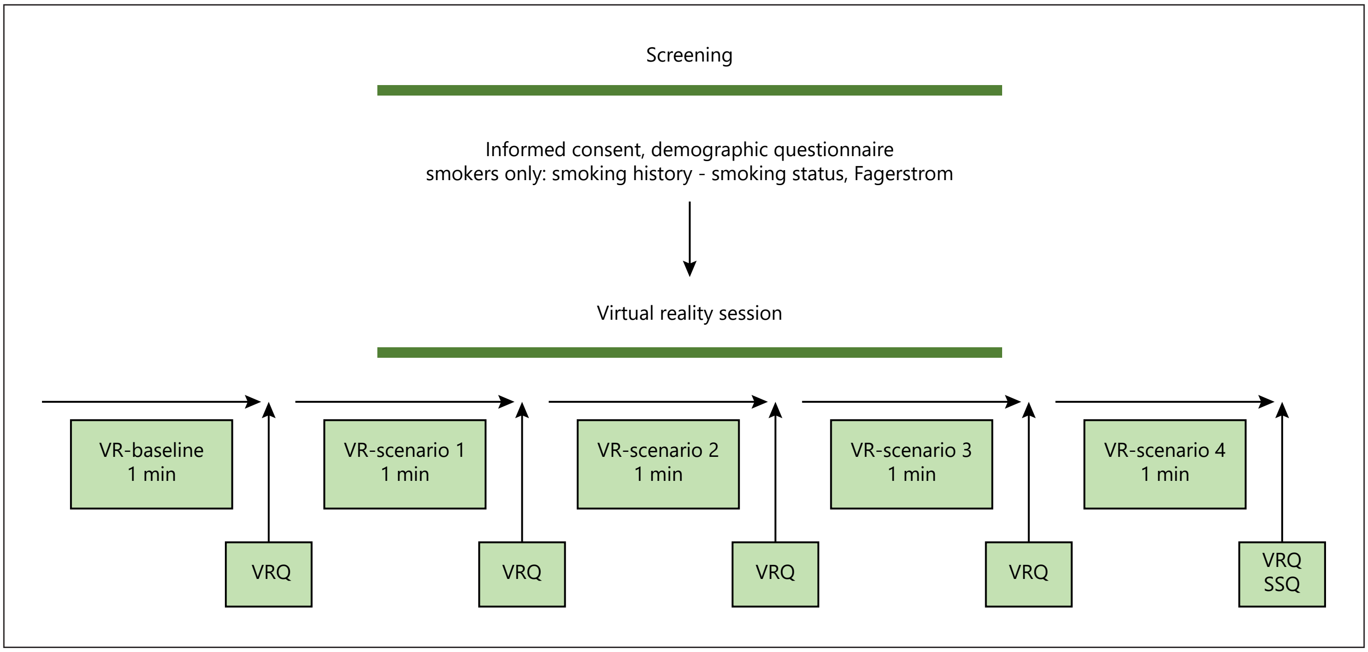

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Fig. 2. Study design flowchart. VAS, Visual Analogic Scale VR Questionnaire; SSQ, Simulator Sickness Questionnaire.

Vecchiato et al. [23]) allowed the assessment of the perception of *familiarity, novelty, comfort, pleasantness, arousal,* and sense of *presence*. The Simulator Sickness Questionnaire (SSQ) [24] is a self-report symptom questionnaire to assess simulator sickness; it provides a total severity score as well as scores for 3 subscales (nausea, oculomotor, and disorientation).

Procedures

The study intervention took place in a single session. Smokers were requested to not smoke at least 1 h before the session. All participants were invited to take place on the workstation chair, and they were instructed about the study procedures, risks, and how to fill out the demographic and smoking questionnaires (the latter in the smoking cohort only). Each participant was immersed at first into a baseline office studio scenario (*STU*) to get acquaintance with the virtual reality and then to the 4 rooms (BED, BAT, KIT, and LIV; Fig. 1) in a semi-randomized and balanced order. Each virtual reality scenario exposure lasted 1 min. Participants had got the freedom to explore the virtual reality scenario by moving their head or by using keys on the computer keyboard to move themselves in the virtual space. At the end of each scenario, participants removed the Oculus Rift and filled out the 11-item VAS scale. All participants had then filled out the SSQ (Fig. 2). The total session lasted approximately 20 min, with an actual 5 min of total VR immersion time.

Data Analysis

Smoking craving was tested in the smoking cohort comparing to zero score values by using the Wilcoxon signed rank test. We also compared the scores for the craving, mood, and perceptual measures with a 2-factor ANOVA for factors cohort (2 levels: smokers and non-smokers) and scenario (4 levels: BAT, BED, KIT, and LIV) followed by a post hoc comparison between cohort levels within each scenario level by using the Bonferroni test.

We performed post hoc multiple comparisons of *alcohol craving, food, familiarity,* and *novelty* scores among the scenario rooms for each cohort by using the Bonferroni test. Separate analysis for male or female participants was performed by 2-way ANOVA.

Results

Table 1 reports the demographic data about the 2 cohorts of non-smokers and smokers. Although more than half of the smokers had a lower level of dependence (54.55%; $N = 18$), a high percentage smoked for >10 years (72.72%; $N = 24$).

Smoking craving was significantly different from a zero value in the smoking cohort in all the scenarios ($p \leq 0.0001$, Wilcoxon signed rank test). There were no significant differences in *Smoking craving* values between the different scenarios: studio (baseline/habituation scenario) = 1.73 ± 0.31; BAT = 1.82 ± 0.33; BED = 1.88 ± 0.31; KIT = 2.03 ± 0.36; and LIV = 1.70 ± 0.30 (mean score ± SEM).

With a 2-factor ANOVA, we tested main effects and interactions of factors cohort and scenario on each dimension score. A significant main effect for cohort was observed for *presence* (F [1, 67] = 10.580, $p \leq 0.01$). Although the factor scenario also induced a significant

Table 1. Demographic data of the 2 cohorts non-smokers and smokers

Characteristic	Non-smokers		Smokers		Total	
	N	%	*N*	%	*N*	%
Sex						
Male	11	30.56	19	57.58	30	43.48
Female	25	69.44	14	42.42	39	56.52
Age, years						
<25	4	11.11	6	18.18	10	14.49
26–30	12	33.33	10	30.30	22	31.88
>31	20	55.56	17	51.52	37	53.62
Highest degree awarded						
High School Diploma	8	22.22	12	36.36	20	28.99
Bachelor's degree	8	22.22	6	18.18	14	20.29
Graduate	20	55.56	14	42.42	34	49.28
PhD	0	0.00	1	3.03	1	1.45
Occupation						
Student	12	33.33	13	39.39	25	36.23
PhD	1	2.78	3	9.09	4	5.80
Researcher	10	27.78	2	6.06	12	17.39
Employee	10	27.78	7	21.21	17	24.64
Others	3	8.33	8	27.70	11	15.94
Years of ex-smokers						
<5	4	11.11	–	–		
>5	3	8.33	–	–		
Years of smoking						
<10	–	–	9	27.27		
10–15	–	–	16	48.48		
>15	–	–	8	24.24		
Cigarettes/day, *n*						
<10	–	–	18	54.55		
10–15	–	–	12	36.36		
>15	–	–	2	6.06		
Fagerström score						
Low	–	–	18	54.55		
Low-to-mod	–	–	9	27.27		
Moderate	–	–	4	12.12		
High	–	–	2	6.06		

Age, M = 35, SD = 10.70. 19.44% ($N = 7$) of the non-smoker sample reported to have stopped smoking. The Fagerström score has been made according to Kennedy et al. [24], where *low* dependence = 1–2 scores; *low-to-mod* dependence = 3–4 scores; *moderate* dependence = 4–6 scores; *high* dependence = 8 or more scores.

main effect on this dimension *presence* (F [3, 201] = 4.263, $p \leq 0.01$), there were no significant factor interactions (for *comfort* and *pleasantness* data, see online suppl. materials at www.karger.com/doi/10.1159/000515301). Post hoc multiple comparison analysis between dimension scores within each scenario found significant differences in all scenarios between smokers versus non-smokers for the *presence* dimension (Fig. 3). A separate analysis for male participants showed a main effect of the cohort for *presence* (F [1, 28] = 5.188, $p = 0.0306$), highlighting that male non-smokers perceived a greater sense of presence than male smokers, similar to what was found in the overall analysis. Furthermore, the factor scenario showed significant main effects also for dimensions *alcohol craving* (F [3, 201] = 5.931, $p \leq 0.001$), *food craving* (F [3, 201] = 4.545, $p \leq 0.01$), *familiarity* (F [3, 201] = 60.67, $p \leq 0.0001$), *novelty* (F [3, 201] = 20.53, $p \leq 0.0001$), and *arousal* (F [3, 201] = 3.463, $p \leq 0.05$). Based on these effects, we investigated whether scores for these dimensions significantly differ across scenarios within each cohort, in order to investigate different dimension patterns. With this aim, we performed a post hoc multiple comparison analysis of dimension scores of each cohort among the scenarios.

Food craving in smokers, but not in non-smokers, showed higher values in the KIT compared to other scenarios, with a significant post hoc difference from the BAT ($p \leq 0.05$, Bonferroni test) (Fig. 4, upper right panel). Similar effect was observed for *alcohol craving* in the KIT and in the LIV of smokers, with scores significantly higher ($p \leq 0.01$, Bonferroni test) than in the BAT (where *alcohol craving* was not significantly different from zero value) (Fig. 4, upper left panel). In non-smokers, *alcohol craving* was not significantly different from zero. A separate analysis for female participants showed a significant cohort effect (F [1, 37] = 12.55, $p = 0.0011$), revealing a lower alcohol craving in female non-smokers compared to female smokers.

Familiarity and *novelty* patterns in the 2 cohorts appeared very similar. Both cohorts showed high values for *familiarity* in all scenarios except in the LIV (significantly lower than other scenarios) (Fig. 4, lower left panel). For *novelty,* both cohorts showed significantly higher score values in the LIV compared to other scenarios (Fig. 4, lower right panel), confirming the complementary, opposite, valence of the dimensions *familiarity* versus *novelty*.

Finally, no main or interaction effects were found in positive and negative mood dimensions. However, a separate analysis in female participants showed that there was a significant main effect for the cohort factor (F [1, 37] = 4.506, $p = 0.0405$) on positive mood, suggesting that female non-smokers experienced a higher positive mood in our indoor virtual environments compared to female smokers.

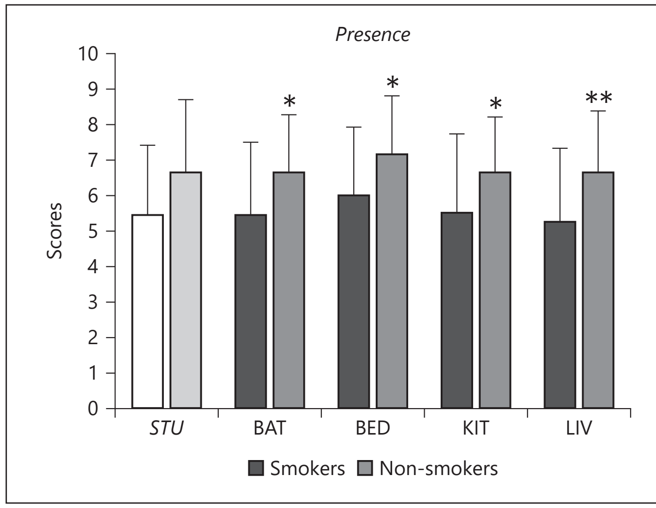

Fig. 3. *Presence* scores for the 2 cohorts in the different scenarios. Mean score values (ordinates + standard error of means) for smokers (open and black columns; $N = 33$ subjects) and non-smokers (light and dark grey columns; $N = 36$ subjects) are shown for the scenarios BAT, BED, KIT, and LIV. Habituation scenario *STU* is also shown as a reference (open column and light grey column, respectively, for smokers and non-smokers). $^{**}p \leq 0.01$ and $^{*}p \leq 0.05$, significant difference between cohorts within the same scenario, Bonferroni post hoc test. BAT, bathroom; BED, bedroom; KIT, kitchen; LIV, living room; STU, studio.

Discussion

Our findings showed that (i) it is possible to elicit context reactivity in smokers in virtual reality, and (ii) these effects are room-dependent and (iii) associated with a lower level of presence; furthermore, (iv) smokers reported higher craving scores for alcohol and food versus non-smokers but equally reacted in terms of *familiarity* or *novelty* (v) with no differences in mood changes. Cigarette craving was significantly induced in smokers in all the VR room scenarios; however, the craving scores are not high. Although we have studied domestic indoor contexts, the effect of smoking ban in indoor public places in Italy during the last 15 years might have influenced the association between smoking craving and indoor contexts. Future studies will have to test this hypothesis, comparing public and private indoor and outdoor virtual environments. The balanced order to scenario exposure during the session let us exclude a smoking craving carryover effect from 1 scenario to the next ones. In our study, the smoking cohort was mainly composed of low and low-to-moderate-dependent smokers with however a relatively long smoking history and moderate intake (i.e., number of cigarettes/day).

Smokers reported *alcohol craving* in all the scenarios but the BAT, a potentially safe domestic context? This suggests a pattern of cross-reactivity to cigarette and alcoholic beverages in these rooms. Smoking and drinking behaviours often occur together, as cues more directly associated with the activity of one (e.g., smoking) can sometimes serve as an implicit cue for the other (e.g., drinking alcohol) [25–27]. Although we did not assess alcohol dependence in our sample, our findings suggest the occurrence of cross-context reactivity in rooms usually associated with both drinking and smoking.

Our data showed a lower level of presence in smokers compared to non-smokers. Gamito et al. [28] did not observe any significant interaction between smoking status and presence, in contrast to studies in alcoholics [29] and

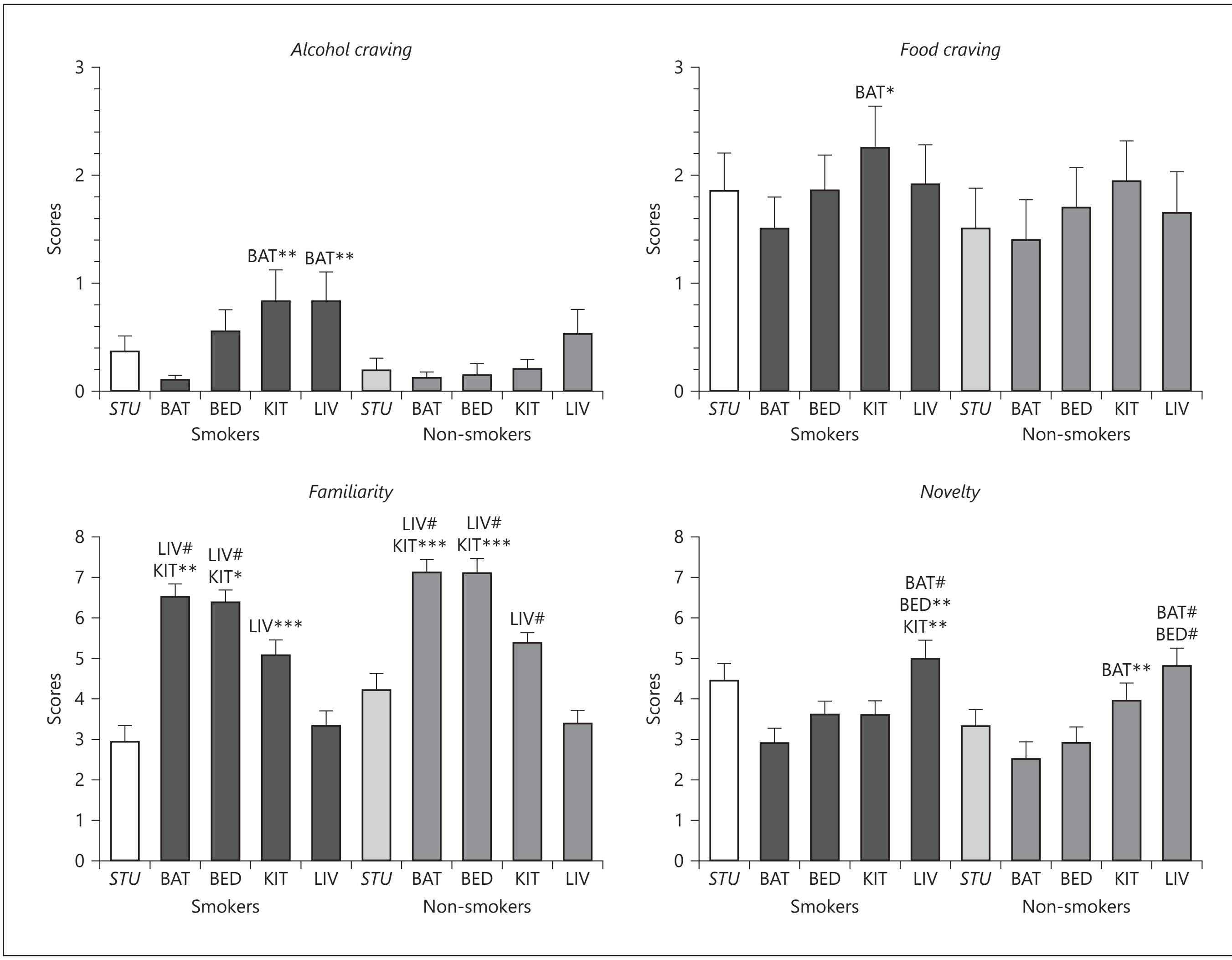

Fig. 4. *Alcohol craving, food craving, familiarity,* and *novelty* scores for the 2 cohorts in the different scenarios. Mean score values (ordinates + standard error of means) for cohorts smokers (open and black columns; $N = 33$ subjects) and non-smokers (light and dark grey columns; $N = 36$ subjects) are shown for the scenarios BAT, BED, KIT, and LIV. Habituation scenario *STU* is also shown as a reference (open columns and light grey columns, respectively, for smokers and non-smokers). $\#p \leq 0.0001$, $^{***}p \leq 0.001$, $^{**}p \leq 0.01$, $^{*}p \leq 0.05$ between scenarios (see scenarios abbreviations) within the same cohort, Bonferroni post hoc test. BAT, bathroom; BED, bedroom; KIT, kitchen; LIV, living room; STU, studio.

cocaine addicts [30], suggesting a more vivid reaction to drug-related stimuli for these types of addicts compared to smokers. Presence is defined as the degree of realism, involvement, and interactions in the virtual simulation, including sensory and attentional processes. Witmer and Singer [31] suggested that presence involves attentional resources more connected to the global scenario rather than to discrete novel elements in the immersive context. Considering that patterns of novelty scores (expression of attention for novel elements) between the 2 cohorts were not different, it appears that the difference in presence was not due to differences in selective attentional processing. On the other hand, we could hypothesize that lower presence was due to impaired global attentional processing in smokers compared to non-smokers. Moreover, Vecchiato et al. [32] showed that presence is correlated with power EEG spectral density of sensorimotor region integration, and we could speculate that this altered cortical function – already seen in smokers by imaging [33–35] – might be the mechanism underlying the reduced global attention.

A major limitation of our study was the lack of biochemical assessment of nicotine intake to assess whether the smoker participants remained abstinent from smoking by at least 1 h before the session. We did not assess smoking craving before the session (a baseline "status" craving) because it was not comparable with the "VR-evoked" craving, even thought it would be important to know whether smokers were different in craving status before to be immersed in the smoking context scenarios. Another limitation was that craving and presence were not continuously measured. A methodological improvement would be to have continuous assessments during the immersion for a more accurate measure of these variables, instead that at the end of the session. It has been in fact recommended to investigate how craving develops during the virtual reality immersion and if there is a score value decline over session time [13].

In conclusion, our study adds new information about smokers' reactivity in virtual reality by using cue-free context and assessing a series of perceptual and craving measures. Virtual reality environments can be effectively used in the treatment of nicotine dependence: the association of immersive virtual reality with exposure therapy might be able to significantly enhance the efficacy of smoking cessation treatment, as demonstrated by several [36] and recent (e.g., [37]) reports. Planning of "motivational healthy" environments may also play a key role for prevention of smoking [38]. Vecchiato and colleagues [23, 32] showed an effect of the aesthetic features of virtual context in perceptual responses. A possible use of VR could be the association with those imaginal retraining protocols shown to be effective for reduction of smoking [39]. Virtual reality lab studies could contribute – together with ecological studies – to identify "positive" contextual features which, when associated with treatment and education, might be able to facilitate safer behaviours and healthy life styles [40, 41].

Statement of Ethics

The study was approved by the Ethics Committee for Clinical Trials, University Hospital Integrated Trust of Verona (Project No. 1334CESC; Protocol No. VR2-2017), and followed the principles of the Helsinki Declaration. The informed consent was obtained from participants.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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Author Contributions

G.B., F.T., T.Z., S.B., and C.C. conceived the study. G.B., F.T., S.F., E.L., and M.D.C. collected data. G.B., F.T., T.Z., and C.C. were involved in analysis and interpretation of data. S.F. prepared the virtual domestic scenarios. G.B., F.T., T.Z., and C.C. drafted the manuscript, and all authors approved the final version. C.C. supervised the entire study.

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