



HAL
open science

Design of a Virtual Cocaine Consumption Scenario for Craving Study

Miguel Gervilla, Flavien Lecuyer, Thomas Lehoux, Julien Anthouard, Luisa Weiner, Christelle Porche, Antonio Capobianco

► **To cite this version:**

Miguel Gervilla, Flavien Lecuyer, Thomas Lehoux, Julien Anthouard, Luisa Weiner, et al.. Design of a Virtual Cocaine Consumption Scenario for Craving Study. The 10th IEEE International Conference on Healthcare Informatics, Rochester, Minnesota, USA, June 11th-14th, 2022, Jun 2022, Rochester, United States. 10.1109/ICHI2022.2022.00046 . hal-03752547

HAL Id: hal-03752547

<https://hal.science/hal-03752547>

Submitted on 17 Nov 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Design of a Virtual Cocaine Consumption Scenario for Craving Study

Miguel Gervilla
iCube
Université Strasbourg
Strasbourg, France
miguel.gervilla@etu.unistra.fr

Flavien Lécuyer
iCube
Université Strasbourg
Strasbourg, France
lecuyer@unistra.fr

Thomas Lehoux
Laboratoire de Psychologie des Cognitions, iCube
Université Strasbourg
Strasbourg, France
t.lehoux@unistra.fr

Julien Anthouard
Association Ithaque
Strasbourg, France
j.anthouard@ithaque-asso.fr

Luisa Weiner
Laboratoire de Psychologie des Cognitions
Hôpitaux Universitaires de Strasbourg
Université Strasbourg
Strasbourg, France
weiner@unistra.fr

Christelle Porche
Hôpitaux Universitaires de Strasbourg
Strasbourg, France
c.nithart@unistra.fr

Antonio Capobianco
iCube
Université Strasbourg
Strasbourg, France
a.capobianco@unistra.fr

Abstract—By providing any wanted situation without the risks associated to it, Virtual Reality (VR) bears a strong potential for Cue Exposure Therapy (CET) related to psychoactive substance use disorders (SUD), as it allows both exposing participants to a great variety of controlled stimuli and making them involved through a strong sense of presence.

However, while Virtual Reality Exposure Therapy (VRET) has already been used successfully in the treatment of several disorders (e.g. tobacco dependence, agoraphobia, social phobias, post-traumatic stress disorder, obsessive-compulsive disorder), its effectiveness still needs to be demonstrated for the treatment of cocaine-related SUD. Most notably, its ability to induce craving must be evaluated.

In this paper, we describe the design and development of a virtual environment made for the treatment of substance use disorder with cocaine users through CET. This environment is also presented in a video (<https://vimeo.com/568320310>).

Index Terms—virtual environment design, cocaine craving, emotional involvement, virtual reality exposure therapy

I. INTRODUCTION

In the context of psychoactive substance use disorders, CET has therapeutic potential [1]. However, due to the risks associated with in vivo exposure and the illegality of substances, current methods of triggering craving - the irrepressible desire to consume the substance - are based mainly on predefined - and sometimes inadapted - visual stimuli, such as photos or videos of the desired substances. These stimuli have the disadvantage of limiting the subject's exposure to a set of stimuli less ecologically valid and thus less powerful at soliciting craving than the actual stimuli [2], which may compromise the effectiveness of the CET approach [3].

The use of VR can improve CET potential by overcoming these limitations. The paradigm of Virtual Reality Exposure Therapy (VRET) makes it possible to exploit dynamic and interactive immersive Virtual Environment (VE) that are specific and ecological to the subject's consumption [4]. VR promotes the emergence of a strong subjective sense of presence in the VE [5] thus eliciting cravings that have been demonstrated to be superior to that of exposure to classical visual stimuli [2], [4], [6]. VRET has already demonstrated that it can enhance the therapeutic effect of traditional CET in several disorder treatments: tobacco dependence [7], agoraphobia, social phobias, post-traumatic stress disorder, obsessive-compulsive disorder [8] and could furthermore encourage people with substance use disorder to engage in therapy [9]. However, to be effective, the VE must be representative of real substance use environments as experienced by the participant: the representativeness significantly mediates craving eliciting by VR [10].

In this paper, we present the design and development of a VR environment for the treatment of substance use disorder with cocaine users. This environment was created in the context of an ongoing study aiming at demonstrating the therapeutic potential of VRET for cocaine use disorder.

This paper is organized as follows: in section II we present the related works to our project. In section III we present the result of a preliminary work aiming at developing and evaluating 3 prototype environments and their empirical evaluation. In section IV we present the design of the final environment we developed. In section V, we present the results of a first study

we led using this environment before concluding in section VI.

II. RELATED WORKS

A. The Use of Virtual Reality in Cue Exposure Therapy

CET are widely indicated in the management of many anxiety disorders and demonstrate effect sizes comparable to in vivo modalities. CET are also indicated in the treatment of psychoactive substance use disorders. However, in this context, their therapeutic potential is limited. In fact, current methods are based mainly on visual stimuli, such as photos or videos of substances, which are non-interactive and not representative of live consumption situations. In addition, several meta-analyses highlight the lack of consistency of the available corpus and question the expectations related to CET [3], [11], [12]. Conklin & Tiffany point out that, despite a strong interest for CET, this paradigm fails to show lasting effects on abstinence in psychoactive substance users [3]. Likewise, Mellentin & al., in a meta-study on alcoholic disorders, underline the lack of evidence on the long-term efficacy of CET compared to conventional treatment in cognitive behavioral therapy [11].

In this context, the paradigm of VRET represents a particularly interesting lever for improving conventional CET. In fact, VR technologies allow the creation of dynamic and interactive immersive VE specific to the patient's consumption situations. For example, the effectiveness of exposure to virtual reality stimuli in triggering craving has been demonstrated to be superior to that of exposure to conventional stimuli [12]. The authors note an increased effectiveness of VRET, compared to exposure therapies to photos or videos, while underlining the need for additional studies to validate this effect. In particular they conclude that a study of the impact of factors influencing presence is necessary. Furthermore, in their systematic review of research on the use of VR in assessment and treatment of addictive disorders, Segawa et al. [13] note that VR provides significant benefits and achieve high levels of ecological validity. However, they also stress that craving provocation in VR is effective across addiction disorders, treatments based exclusively on VRET to drug related cues as shown heterogenous results. These insights confirm suggestion from a previous review from Hone-Blanchet et al. [2] suggesting the need for further studies on the matter.

A study focused on the use of Virtual Reality Exposure (VRE) and aimed at assessing the effectiveness of this paradigm in triggering craving in patients in a study involving 11 cocaine users [6]. Users who were immersed in VR environments specific to cocaine use reported a significant increase in craving, a significant decrease in positive affect, as well as an increase of heartbeat, when compared to reference levels. However, their study did not use multi-item craving assessment, and thus lacks a proper assessment of craving elicitation levels [14].

It therefore emerges from the analysis of the literature that the paradigm of VRET is of great interest to all the actors involved in the care of individuals with substance use disorders but that their effectiveness has yet to be validated empirically.

Furthermore, the accompanying clinical practices including these tools are still to be defined [2].

B. Craving, Presence and Ecological Validity

Craving exposure requires at first craving eliciting. In a review of the craving major behavioural and cognitive models [15], classical conditioning is introduced as the main mechanism by which an exposure to particular stimuli will automatically elicit craving. More particularly, classical conditioning model argues that a repeated cocaine use (unconditioned stimulus) in exposure to neutral stimuli (e.g. a syringe) will induce an association between the neutral stimuli and the unconditioned response of craving. A simple exposure to the syringe (conditioned stimulus) will then result in eliciting cocaine craving (conditioned response). Hence, eliciting craving in an exposure context will require to expose oneself not only to the very specific stimuli conditioned to craving, but also to their dynamic way to interact between each other [16]. VR, through a more immersive and interactive experience elicits presence which, in turn, can encourage intense craving [17]. It thus has the potential to overcome the intrinsic limitations of traditional static pictures exposure (PE) [2].

Presence, defined as *the feeling of being there* in a digital environment, rather than in the actual physical place of a user, is a key factor in any VR experience [18]. It is strongly suggested that immersion - or the technological quality of a media - has only a medium sized effect on the feeling of presence [19]. Presence seems to be solicited not only through the quality of the visual stimuli of the environment, but also through the systems' interactive capability : the feeling of presence emerging from displays quality and interactive capability alike, creating *the sense that the environment is actually happening (the plausibility illusion)* [19], [20].

Positive correlation has been observed between the sense of presence and the emotional experience [17]. In their study comparing post-immersion in occasional and heavy alcohol drinkers, they show a correlation between presence and craving outcomes. More specifically, craving was linked to the *ecological validity* of the environment - i.e. "the tendency to perceive the environment as lifelike and real" - as assessed by the ITC sense of presence inventory [21]. It is thus reasonable to assume that, in the context of VRE, a higher sense of presence will be correlated with higher levels of craving and that ecological validity of the environment will be a key factor in the effectiveness of the designed environments.

III. FIRST STEP IN DEFINING ECOLOGICAL ENVIRONMENTS

Our approach to VRET to craving consists in designing environments with a focus on ecological validity: in order to better induce craving, our VEs should match a real life consumption situation that the users might have already encountered [10]. As a first step towards this end, we led semi-structured interviews with 4 cocaine users in order to identify what they thought would be the most representative consumption situations. The interviews and preliminary tests were

carried by psychologists with voluntary participants seeking help at the **name removed for anonymity** prevention center associated to this work. Throughout the interviews, users were encouraged to relate what would be the according consumption scenario. Three scenarios emerged from these interviews:

A. Urban Scenario

- **Environment** : a neighborhood of a common city containing bars and towers of buildings with a parking lot in the middle.
- **Scenario** : the trade of a cocaine bag is done in the middle of the parking lot. After that, the user can use the drug in a back alley.

B. Festive Scenario

- **Environment**: a bar with a festive atmosphere inside with people drinking alcohol.
- **Scenario**: a group of people are gathered around one of the tables trying to protect themselves from the gaze of others to exchange bags of cocaine. At another table, a person is consuming on the table itself, causing discontent around it.

C. Apartment Scenario

- **Environment**: A calm apartment environment.
- **Scenario**: Three virtual characters come to the apartment: a close friend and a couple. Each has their own product and places it on a table in front of a sofa to prepare it. The environment includes bottles of water, some alcohol and tobacco, a TV playing music videos.

From these elements, we created 3 distinct test environments corresponding to the identified scenarios and led some pre-tests with 3 participants with cocaine SUD.

All participants tested the three environments and were then invited to participate in a semi-structured post-test interview aiming at collecting their impressions and informal evaluation. The *urban scenario* was considered the least plausible by the participants. It seemed too empty and artificial and the insights on how to transform this environment were divergent. The *festive scenario* was well received but lacked realism. Similarly, the participants suggested divergent modifications (buying the product indoors and/or outdoors, people coming and going with different behaviors, different consumption situations in the main room or in the toilets, etc.). Bringing these complex scenario alternatives to the environment seemed too complicated for our preliminary test of eliciting craving in cocaine users through VR. The *apartment scenario* was the most consensual and the most appreciated. During the semi-directive interviews, the participants were asked what could make them crave for cocaine consumption in the presented environments. In their responses, the participants made some common remarks that led us to extract the following insights for designing our new environment:

1) *Insight 1: Consumption mode*: The environment should allow to chose between different consumption mode, according to the habit of each participant - smoking, snorting and injecting.

2) *Insight 2: Interaction and props*: The environment should allow to see all the props necessary for the preparation of the consumption and to be able to interact with it in order to prepare the future consumption. This should bring the participant even closer to a real situation and might at the same time make him/her wait before consuming, which should in turn reinforce craving.

3) *Insight 3: Familiarity and atmosphere*: The environment should feel familiar and comfortable, and promote a cosy atmosphere through, for example, lights and music.

4) *Insight 4: People*: The environment should allow social interaction, which is known to represent a strong factor in cocaine abuse [22]. The participants reported that seeing other people consuming might not only trigger craving but also invite them to use or prepare cocaine and thus make them feel comfortable in the environment.

From this preliminary experience, we chose to focus on the development of an improved apartment scenario - since it appeared to be the one a majority of participants could relate to - that would implement all the 4 insights listed above. This environment is described in section IV.

IV. VIRTUAL ENVIRONMENT DESIGN

To implement the 4 insights listed in section III, we propose an environment with: (1) a scenario that can induce the craving with 3 different consumption modes, (2) the presence of interactive props that can be manipulated to deal, prepare and consume products, (3) a fully navigable generic apartment with ambient elements, and (4) animated virtual agents to simulate the social pressure.

For therapeutic purposes, the final environment should not only efficiently induce craving but also be easy to use by the therapist in the context of a CET setting. To this end, we added to the previous characteristics the following design principles:

- The craving must be induced by the situation only and not through cues unrelated to the environment, e.g. therapist insights or external stimuli;
- For ecological and comparative purposes, several craving activation phases, corresponding to ecological situations of drug use, must be present;
- For the sake of sense of presence and therapeutic constraints, the participant must be able to complete the experiment without a need for an external intervention.

A. Consumption Mode

We developed 4 separate versions of the apartment scenario. For experimental purpose, the first scenario present a consumption neutral environment. In this condition, any reference to consumption material or social situation is absent in order to avoid inducing any craving. Instead, the apartment is decorated with a set of picture frames hanged on the walls, presenting emotionally neutral pictures taken from the OASIS database [23].

The 3 other scenarios implement 3 consumption options to chose from, according to the consumption habits of the participant: smoking, snorting and injecting product. For each



Fig. 1. The three environments designed for our preliminary approach: urban, festive and apartment.

condition, the corresponding substance and harm reduction materials are present in the environment (see Figure 2). In these environments, the participant is provided with virtual hands that are controlled with the VR controllers.

B. Interaction and Props

The objects displayed for the drug use and harm reduction can be manipulated with semi-realistic interactions, i.e. grasped and manipulated freely, in order to provide both a greater sense of presence and a higher chance of inducing the craving, as the manipulation plays an important part in the activation of craving (regarding cigarette smoking) [24].

C. Familiarity and Atmosphere

To help the participants identify the virtual environment as their own for the experiment, the rest of the apartment is voluntarily designed in a generic way, with little decoration (see Figure 3).

In order to help the participant be at ease, a music chosen at the start of the experiment is played during the entire duration of the experiment. To complement it, a video clip is also played on the TV next to where the drug use takes place.

D. People

To replicate the social interaction, the environment integrates 3 virtual agents. As presented in Figure 4, the virtual agents are designed to look like people the participants could consume with on a standard condition. Those virtual agents use cocaine with the same condition as the participant, and invite them to start the manipulation phase, in which the participant can simulate the preparation and use of cocaine (see Figure 3).

In order to make those virtual agents more realistic and provide a better immersion, they have prerecorded dialogues revolving around common discussion topics (e.g., cinema, vacations, ...) played during the manipulation of the virtual substance. They also have specific dialogues to accompany the participant during the transition to this phase. Indeed, the virtual agents announce themselves when entering the apartment, before inviting the participant to join them.

To avoid any bias concerning a possible induction of craving coming from the dialogues with the virtual agents, the dialogues do not mention directly the substance. However, they manipulate the same material as the participant, and may help them if some of the material falls, in order to increase the sense of presence in the environment.

E. Script

The experience is controlled by a script, created with the Petri-graph based scenario model #SEVEN [25], defining 3 phases with a fixed timing, as illustrated in Figure 5. The participant starts in the environment with a mobile phone in his hand, displaying a message to be sent.

The first phase starts when the message is sent. During 1 minute, the participant is free to move around the apartment, waiting for the virtual agents to join him. This phase allows for the sensation of craving to grow slowly, as the participant is made aware of what follows but has to wait for it.

At the end of the first phase, the virtual agents enter in the virtual apartment and start setting up the material for the third phase. At the end of this phase, which is timed to last 2 minutes maximum, the participant is invited to join them, starting the third and final phase.

The final phase of the experience involves the manipulation of the product during 7 minutes. During this phase, the participant is invited to build and use the product repeatedly, with the objective of inducing the craving during the manipulation and releasing it during the use.

V. APARTMENT SCENARIO EVALUATION

After designing and developing the environment, we led an experimental evaluation with voluntary participants, all suffering from cocaine use disorder and seeking therapeutic help at the Ithaque facility.

A. Hypothesis

This pilot study is part of a long-term research project aiming to define and experimentally validate a VRET protocol to treat cocaine use disorders. Our objective with the

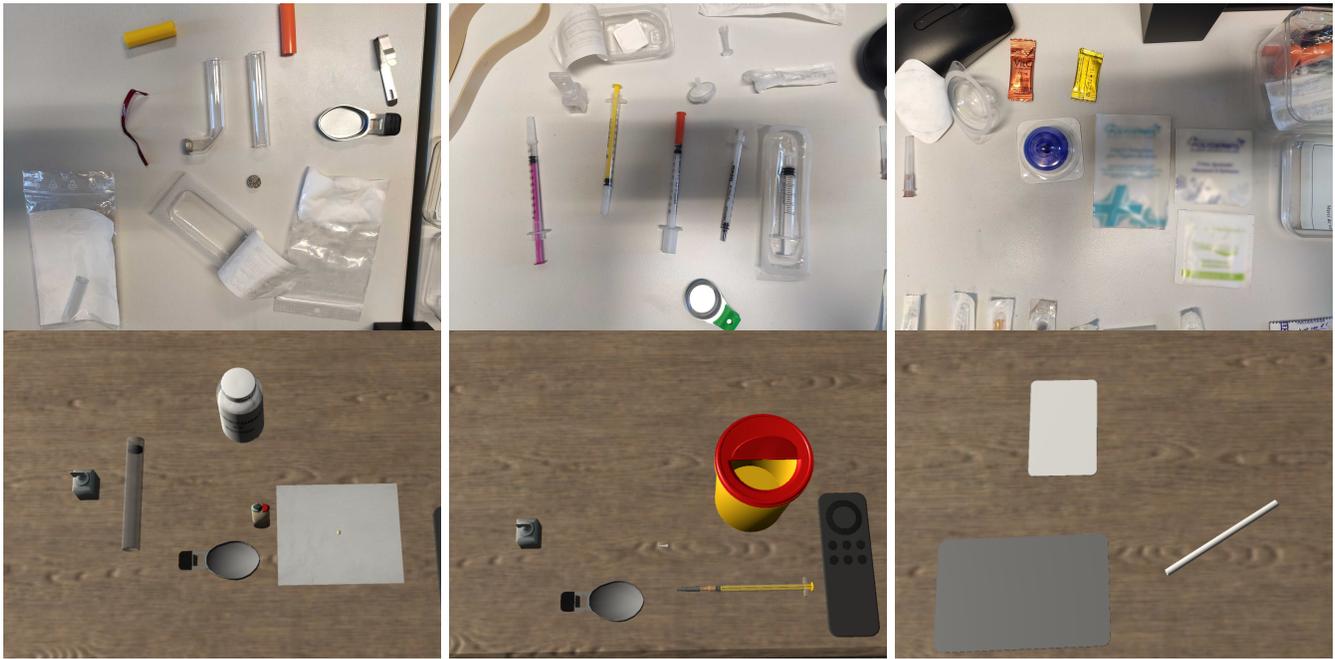


Fig. 2. Cocaine-related cues for the injection environment (reference objects and virtual representations). From left to right: smoking environment, injection environment, snorting environment.

present study was to validate in an early stage of our long term experiment that the designed virtual environment would indeed solicit craving. Our main hypothesis in the present is the following : when compared to a baseline situation or a neutral VR environment exposure, exposure to the tested environment significantly increases craving, as assessed by the CCQ-Brief questionnaire.

B. Participants

1) *Inclusion:* The inclusion criteria to participate in the study were the following:

- having normal - or corrected to normal - vision and hearing
- to be 18 years old or older and not to be under legal protection, guardianship or curatorship
- reporting having used cocaine at least once in the 30 days preceding the experiment
- to be able to understand the objectives and risks of the research and to give informed, dated and signed consent
- to be in the process of an active monitoring at the Ithaque facility. We wish to stress that all the people attending the association do so freely and choose to actively engage in a process of control or exit from their dependence.
- not to present a risk of suicide, a (hypo-) manic episode or a psychotic disorder according to the criteria of the Mini International Neuropsychiatric Interview (MINI; DSM-IV; [26])

These criteria were checked during an inclusion interview that took place before any immersion in the developed environments (see sec. V-C) chosen to ensure that the target audience would receive proper care, respect and monitoring

from well-known professionals with whom a relationship of trust is already established.

Any participant could withdraw from the study at any time by simple oral declaration or by email to one of the study organizers. He could also ask the already collected data to be returned or deleted. However, none of the included participants withdrew from the study.

This study was approved by the ethical comity from the University of Strasbourg and given the following approval ID 2021-A00242-39. All the test were performed by a trained psychologist working at the Ithaque facility and specialized in CET and addictive behaviors, hereinafter referred to as the experimenter.

2) *Participants demography:* 20 people, seeking therapeutic assistance at our organization, were recruited to participate in the experiment. Participants first passed the MINI (DSM-IV) questionnaire [26] to check for potential exclusive risks (high suicidal risk, manic or hypo-maniac, and psychotic episode). Following this pre-inclusion phase, 10 participants (1 female and 9 male) - aged from 26 to 48 ($m=32.4$, $sd=6.62$) - were finally invited to continue the experiment. Most of the participants (7) manifested both a cocaine dependence and abuse, as assessed by the MINI (DSM-IV) [27].

Although some of the participants used cocaine through different modes, they were asked to declare their preferred mode. They were then proposed to experiment the corresponding scenario: 3 chose the snorting scenario, 5 chose the smoking scenario, and 2 chose the injecting scenario.



Fig. 3. Two views of the environment. On the top image, a view of the living-room with a table, a sofa and a TV. On the bottom one, a virtual agent proposing to the participant some consumption material.

C. Protocol

The experiment took place throughout 3 sessions for each participant, each separated by a few days. After each session, the participants participated in a therapeutic follow-up with a psychologist to help them manage the craving. They were allowed to leave the facility after successfully overcoming the desire for consumption caused by exposure to the environment.

The first session (duration: 1h10mins) started with the explanation of the experimental protocol and the verification for potential risks that justified the exclusion of some participants from the experiment. During the first session, the participants were also introduced to VR with a 10 minute immersion in a tutorial environment (see Figure 6 top). At the end of the immersion, the participants were asked to fill the SSQ questionnaire (4-point Likert scale to assess cybersickness) [28] and the self-made VRESQ (Virtual Reality Environment Satisfaction Questionnaire) questionnaire (see Figure 7). This VRESQ questionnaire was created for this experiment for the purpose of estimating the perceived quality of the environments presented to the participants.

The second session (duration: 1h20mins) did not include



Fig. 4. The three virtual agents included in the environment

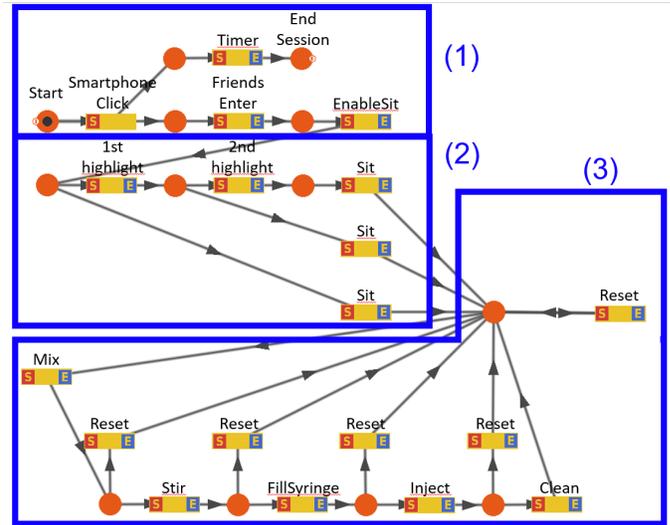


Fig. 5. Scenario for the injection environment, with its 3 phases: (1) Waiting (2) Situation setup (3) Drug use. Each phase is defined as a Petri-graph interacting with the VE through its transitions, enriched with Sensors and Effectors linked to the environment

any immersion. Instead, the participants discussed with the experimenter, and were asked to fill the CCQ-Brief (Cocaine Craving Questionnaire - French Version) questionnaire [29] to assess the cocaine craving level on a baseline condition which consisted of a 10mins visual exposure to neutral pictures displayed from a computer.

Finally, the third session (duration : 1h15mins) comprised two periods of immersion. First, the participants experienced immersion in a neutral version (see Figure 6 bottom) of the apartment environment. In this neutral condition, the consumption phase was replaced by a visual task, in which participants

had to unveil picture frames – containing emotionally neutral images [23] – in the environment and look at them. The neutral condition lasted 10mins, after which the participants were asked to fill several questionnaires: SSQ, VRESQ, PQ (Presence Questionnaire, on a 7-point Likert scale) [30] and CCQ-Brief.

After a 10mins pause, participants followed with the immersion in the cocaine environment adapted to their usual consumption modality. This second immersion lasted 10 minutes, in accordance to the scenario described in section IV. Following the immersion, the participants filled the questionnaires again (SSQ, VRESQ, PQ, CCQ-Brief).



Fig. 6. On top, the tutorial environment. On the bottom figure, the neutral condition

At the end of each session, the participants were offered a 10€ food voucher.

D. Results

According to our sampling size estimation computed with G*Power, 23 participants were required to detect a significant statistical difference of craving scores between our VR neutral and cocaine conditions with a statistical power greater than 0.8 and a significance threshold alpha of 0.05. Given the

From -3 to 3 (-3=Completely disagree, 0=neutral, 3=Completely agree):

- 1) I found the apartment and furniture convincing; I felt that the environment corresponded to an existing apartment.
- 2) I felt that the interactions with the environment were easy and natural.
- 3) I felt that the characters were credible.
- 4) I felt that the consumption situation was representative of a real situation, and corresponded to an experience I lived or could live.
- 5) I found that the the device was adapted and correctly adjusted (image and sound) to propose a good immersive experience.
- 6) I was easily transported by the experience, I easily projected myself as if it was a real experience.
- 7) (*Open question*) In your opinion, how could we improve the VR experience we proposed?

Fig. 7. VRESQ questionnaire (translated in english) used to assess the ecological validity of the environment. Items 3 and 4 were only used in the cocaine condition.

relatively low number of participants ($n=10$), we decided to not perform and report here inferential statistics but only descriptive statistics and correlation values.

The results obtained from the experiment showed a good activation of the craving in the virtual cocaine environments, compared to both the baseline and the virtual neutral condition, as can be seen in Figure 8 (left). In particular, we observed in participants a strong increase of cocaine craving when exposed to the virtual cocaine condition (Cohen's $d = 1.16$; $m=31$; $sd=18.15$), compared to when exposed to the virtual neutral condition ($m=15.8$; $sd=7.97$). In addition, we also observed a moderate increase of cocaine craving when exposed to the virtual cocaine condition (Cohen's $d = 0.63$), compared to when exposed to the baseline condition ($m=21.8$; $sd=11.25$). Interestingly, cocaine craving was observed as moderately lower when exposed to the virtual neutral condition (Cohen's $d = -0.62$), compared to when exposed to the baseline condition.

We also noted good scores at the PQ questionnaire. Indeed, and as can be seen in Figure 8 (middle), the participants felt a strong sense of presence in both the neutral and cocaine conditions. Surprisingly, however, we found no correlation between the reported sense of presence and CCQ-Brief levels neither in the *neutral condition* ($r(8) = -0.12$, $p = 0.62$) nor in the *Cocaine condition* ($r(8) = -0.01$, $p = 0.51$). These results suggest that if our forthcoming study shows a significant increase in craving using VRE, further research should be dedicated in assessing the aspects of VR experience that are related to this observation.

Finally, the participants reported during post-test debriefs that the experience "was great" and that they could "feel like being in the room". However, some of them pointed out that the virtual agents animation was sometimes lacking realism, and that the apartment felt bleak. Despite this drawback, the ecological validity assessed by the VRESQ questionnaire was

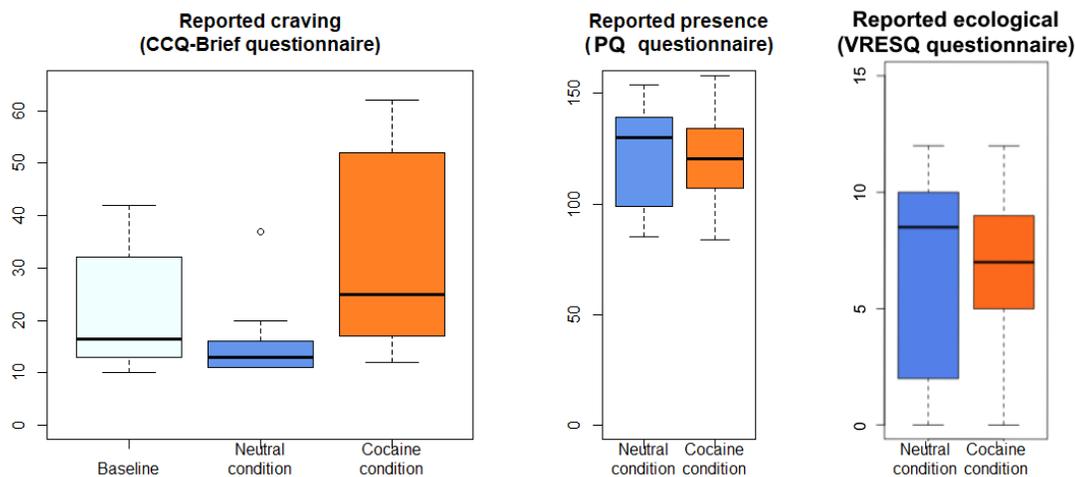


Fig. 8. Left: Cocaine craving results from the CCQ-Brief questionnaire, $Cohen's\ d(neutral, cocaine) = +1,16$. Middle: Presence results from the PQ questionnaire. Right: Ecological validity results assessed by the VRESQ questionnaire.

high (see Figure 8, right). We found no correlation between the reported VRESQ and CCQ-Brief levels neither in the *neutral condition* ($r(8) = -0.27, p = 0.44$) nor in the *Cocaine condition* ($r(8) = -0.27, p = 0.44$).

These first results are really encouraging. They suggest that a VRE designed to comply with an ecological substance consumption situation can provoke craving arousal with a strong effect (cf. Figure 8, Cohend's $d = 1.16$). The moderate difference of craving intensity between our baseline and VR neutral conditions (Cohen's $d = -0.62$) was surprising, considering that the same set of neutral stimuli was used in both conditions. One hypothesis to explain this phenomena could be that the use of VR, through virtual embodiment, alters the perception of one's physical body and could diminish the perception of craving-related physical sensations, thus provoking a decrease in self-reported craving. Higher self-reports of craving intensity in our baseline condition (pictures-based exposure) could also be explained by the fact that its exposure modality, as a static procedure, may bother and frustrate the participant (as verbally self-reported), thereby exacerbating their craving levels. We will further explore this phenomenon in our follow up experients.

VI. CONCLUSION

In this paper, we presented the design of a virtual environment created to induce cocaine craving for regular users. A first phase of experiment was conducted on three environments, designed from the past experience described by people with cocaine use disorder: a urban environment, a festive environment and an apartment. The first tests with those environments showed that the activation of the craving was helped through the consumption mode, the presence of interactions and props, the familiarity of the setup and the presence of social interaction in the context of substance use.

We then designed a second environment, adapted from the apartment condition of the first experimentation phase. For this environment, we focused on the creation of a consumption situation which could remind the participants of their own experience, in order to activate more efficiently the craving. To that end, three substance consumption modes were defined (smoking, snorting, injecting), to adapt to the preference of the participants.

This environment, used in an ongoing study on the therapeutic potential of VRET for cocaine use disorders, showed good results in eliciting cocaine craving. Indeed, the exposure to the in the VR environment with cocaine cues demonstrated a higher self-reported craving compared to when exposed to the same environment with neutral cues and without any consumption cues. Participants also reported a positive experience with the environment, along with a strong sense of presence during the experiment. In a forthcoming study implementing the same protocol, we will seek to further understand the influence of the ecological validity and the interactions of the different components of presence in building craving [17]. To that end, future works would include more participants as a way to get a better statistical power over the performed analyses.

ACKNOWLEDGEMENT

We would like to thank Gauthier Ghitti and Claire Jermann who gave their voice to the virtual agents. This work has been published under the framework of the Idex University of Strasbourg and has been supported by the French government funding managed by the National Research Agency under the Investments for the Future program (PIA) with the grant ANR-21-ESRE-0030 (CONTINUUM project) and the French National Cancer Institute (INCa) and the Public Health Research Institute (IReSP) as part of the Thomas Lehoux's doctoral funding SPADOC21 (#AAC21-SPA-04).

REFERENCES

- [1] T. Martin, S. D. LaRowe, and R. Malcolm, "Progress in cue exposure therapy for the treatment of addictive disorders: A review update," *The Open Addiction Journal*, vol. 3, no. 1, p. 92–101, Oct 2013.
- [2] A. Hone-Blanchet, T. Wensing, and S. Fecteau, "The Use of Virtual Reality in Craving Assessment and Cue-Exposure Therapy in Substance Use Disorders," *Frontiers in Human Neuroscience*, vol. 8, p. 844, 2014. [Online]. Available: <https://www.frontiersin.org/article/10.3389/fnhum.2014.00844>
- [3] C. A. Conklin and S. T. Tiffany, "Applying extinction research and theory to cue-exposure addiction treatments," *Addiction*, vol. 97, no. 2, pp. 155–167, 2002. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1046/j.1360-0443.2002.00014.x>
- [4] M. F. Kuntze, R. Stoermer, R. Mager, A. Roessler, F. Mueller-Spahn, and A. H. Bullinger, "Immersive virtual environments in cue exposure," *CyberPsychology & Behavior*, vol. 4, no. 4, p. 497–501, Aug 2001.
- [5] H. T. Regenbrecht, T. W. Schubert, and F. Friedmann, "Measuring the sense of presence and its relations to fear of heights in virtual environments," *International Journal of Human-Computer Interaction*, vol. 10, no. 3, p. 233–249, Sep 1998.
- [6] M. E. Saladin, K. T. Brady, K. Graap, and B. O. Rothbaum, "A preliminary report on the use of virtual reality technology to elicit craving and cue reactivity in cocaine dependent individuals," *Addictive Behaviors*, vol. 31, no. 18, pp. 1881–1894, 2006. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0306460306000153>
- [7] C. S. Culbertson, S. Shulenberg, R. De La Garza, T. F. Newton, and A. L. Brody, "Virtual reality cue exposure therapy for the treatment of tobacco dependence," *Journal of cyber therapy and rehabilitation*, vol. 5, no. 1, pp. 57–64, 2012. [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4204479/>
- [8] M. Lognoul, J. Nasello, and J.-M. Triffaux, "La thérapie par exposition en réalité virtuelle pour les états de stress post-traumatiques, les troubles obsessionnels compulsifs et les troubles anxieux: indications, plus-value et limites," *L'Encéphale*, vol. 46, no. 4, p. 293–300, Aug 2020.
- [9] A. Garcia-Palacios, H. G. Hoffman, S. Kwong See, A. Tsai, and C. Botella, "Redefining therapeutic success with virtual reality exposure therapy," *CyberPsychology & Behavior*, vol. 4, no. 3, p. 341–348, Jun 2001.
- [10] A. C. Traylor, D. E. Parrish, H. L. Copp, and P. S. Bordnick, "Using virtual reality to investigate complex and contextual cue reactivity in nicotine dependent problem drinkers," *Addictive Behaviors*, vol. 36, no. 11, pp. 1068–1075, 2011. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0306460311001948>
- [11] A. I. Mellentin, L. Skøt, B. Nielsen, G. M. Schippers, A. S. Nielsen, E. Stenager, and C. Juhl, "Cue exposure therapy for the treatment of alcohol use disorders: A meta-analytic review," *Clinical Psychology Review*, vol. 57, pp. 195–207, 2017. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0272735817301058>
- [12] E. Malbos, L. Boyer, and C. Lançon, "L'utilisation de la réalité virtuelle dans le traitement des troubles mentaux," *La Presse Médicale*, vol. 42, no. 11, pp. 1442–1452, 2013, gynécologie endocrinienne. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0755498213005629>
- [13] T. Segawa, T. Baudry, A. Bourla, J.-V. Blanc, C.-S. Peretti, S. Mouchabac, and F. Ferreri, "Virtual Reality (VR) in Assessment and Treatment of Addictive Disorders: A Systematic Review," *Frontiers in Neuroscience*, vol. 13, p. 1409, 2020. [Online]. Available: <https://www.frontiersin.org/article/10.3389/fnins.2019.01409>
- [14] S. Glautier and S. T. Tiffany, "Methodological issues in cue reactivity research," *Addictive behaviour: Cue exposure theory and practice.*, pp. 75–97, 1995.
- [15] M. D. Skinner and H.-J. Aubin, "Craving's place in addiction theory: Contributions of the major models," *Neuroscience & Biobehavioral Reviews*, vol. 34, no. 4, pp. 606–623, 2010. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0149763409001900>
- [16] D. C. Drummond, T. Cooper, and S. P. Glautier, "Conditioned learning in alcohol dependence: implications for cue exposure treatment," *British Journal of Addiction*, vol. 85, no. 6, pp. 725–743, 1990. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1360-0443.1990.tb01685.x>
- [17] J. Simon, A.-M. Etienne, S. Bouchard, and E. Quertemont, "Alcohol craving in heavy and occasional alcohol drinkers after cue exposure in a virtual environment: The role of the sense of presence," *Frontiers in Human Neuroscience*, vol. 14, p. 124, Mar 2020.
- [18] M. Slater, "Measuring presence: A response to the witmer and singer presence questionnaire," *Presence: Teleoperators and Virtual Environments*, vol. 8, no. 5, p. 560–565, Oct 1999.
- [19] J. J. Cummings and J. N. Bailenson, "How immersive is enough? a meta-analysis of the effect of immersive technology on user presence," *Media Psychology*, vol. 19, no. 2, p. 272–309, Apr 2016.
- [20] M. Slater, "Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments," *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 364, no. 1535, p. 3549–3557, 2009.
- [21] J. Lessiter, J. Freeman, E. Keogh, and J. Davidoff, "A cross-media presence questionnaire: The itc-sense of presence inventory," *Presence: Teleoperators and Virtual Environments*, vol. 10, no. 3, p. 282–297, Jun 2001.
- [22] J. R. McKay, M. J. Rutherford, A. I. Alterman, J. S. Cacciola, and M. R. Kaplan, "An examination of the cocaine relapse process," *Drug and Alcohol Dependence*, vol. 38, no. 1, pp. 35–43, 1995. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S037687169501098J>
- [23] B. Kurdi, S. Lozano, and M. R. Banaji, "Introducing the open affective standardized image set (OASIS)," *Behavior research methods*, vol. 49, no. 2, pp. 457–470, 2017.
- [24] W. G. Shadel, R. Niaura, and D. B. Abrams, "Effect of different cue stimulus delivery channels on craving reactivity: comparing in vivo and video cues in regular cigarette smokers," *Journal of Behavior Therapy and Experimental Psychiatry*, vol. 32, no. 4, pp. 203–209, 2001. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0005791601000350>
- [25] G. Claude, V. Gouranton, R. Bouville Berthelot, and B. Arnaldi, "Short Paper: #SEVEN, a Sensor Effector Based Scenarios Model for Driving Collaborative Virtual Environment," in *ICAT-EGVE, International Conference on Artificial Reality and Telexistence, Eurographics Symposium on Virtual Environments*, T. Nojima, D. Reiners, and O. Staadt, Eds., Bremen, Germany, Dec. 2014, pp. 1–4. [Online]. Available: <https://hal.archives-ouvertes.fr/hal-01086237>
- [26] Y. Lecrubier, D. Sheehan, E. Weiller, P. Amorim, I. Bonora, K. Harnett Sheehan, J. Janavs, and G. Dunbar, "The mini international neuropsychiatric interview (mini): a short diagnostic structured interview: reliability and validity according to the cid," *European Psychiatry*, vol. 12, no. 5, pp. 224–231, 1997. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S0924933897832968>
- [27] D. V. Sheehan, Y. Lecrubier, K. H. Sheehan, P. Amorim, J. Janavs, E. Weiller, T. Hergueta, R. Baker, G. C. Dunbar *et al.*, "The mini-international neuropsychiatric interview (mini): the development and validation of a structured diagnostic psychiatric interview for dsm-iv and icd-10," *Journal of clinical psychiatry*, vol. 59, no. 20, pp. 22–33, 1998.
- [28] R. S. Kennedy, N. E. Lane, K. S. Berbaum, and M. G. Lilienthal, "Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness," *The International Journal of Aviation Psychology*, vol. 3, no. 3, pp. 203–220, 1993. [Online]. Available: https://doi.org/10.1207/s15327108ijap0303_3
- [29] L. Karila, E. Seringe, A. Benyamina, and M. Reynaud, "The Reliability and Validity of the French Version of the Cocaine Craving Questionnaire- Brief," *Current Pharmaceutical Design*, vol. 17, no. 14, pp. 1369–1375, 2011. [Online]. Available: <https://www.ingentaconnect.com/content/ben/cpd/2011/00000017/00000014/art00008>
- [30] B. G. Witmer, C. J. Jerome, and M. J. Singer, "The Factor Structure of the Presence Questionnaire," *Presence: Teleoperators and Virtual Environments*, vol. 14, no. 3, pp. 298–312, 06 2005. [Online]. Available: <https://doi.org/10.1162/105474605323384654>