A virtual Arm to Stop Smoking, A Pilot Perceptual Learning Experiment

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Abstract: Cigarette smoking is a complex process of conditioning with generalized stimuli and sustained reinforcement of a psychoactive substance (nicotine). Most of the virtual reality (VR) therapies for addictions are oriented on a cue-reactivity approach, cue-exposure therapy (CET). Our pilot experiment is based on operant conditioning, which is characterized by an action–outcome strategy. We designed a virtual arm able to catch and crush cigarettes, which created an action-exposure (AE) in a VR environment. We observed subjects who participated in four (4) therapy sessions in which they had to crush 25 cigarettes in each session.

The main goal of our study is to explore the usability of this method by smokers and to find out if it can produce some clinical evidence of outcomes by modifying craving and smoking behaviours. In this paper we are submitting the preliminary observations of the first sixteen heavy smokers who participated in our clinical trial.

INTRODUCTION

Smoking cigarettes induces substance dependence with a combination of cognitive, behavioural and physiological symptoms. There is a pattern of repeated self-administration that usually results in tolerance, withdrawal and compulsive drug-taking behaviour (DSM IV-TR, 2000). For example, a one pack a day smoker puts his hand to his mouth an average of 90,000 times a year. It's well known that 70-80% of smokers relapse after their first attempt at quitting and require several more concentrated efforts before becoming smoke free. A ten-year personal clinical survey of 3,700 smokers showed that 50.6% had quit smoking. This was the result of many sessions in our NICOT* program based on the AHCPR 1996, 2000 and WHO 2002 guidelines. Smokers who failed often found themselves at a dead end and despite of their high level of motivation, they were unable to find a solution to their addiction.

VR therapy is an up-and-coming technology that offers new opportunities for relief of certain addictive behaviours (Smith, J. G. 2003). Kwon H. et al., 2006, described the craving as a Pavlovian conditioning or respondent conditioning (cue-outcome). The contexts and objects that become conditioned stimuli (CS) can give rise to the addict's urge (conditioned response: CR) to use the addictive substance. After the conditioning, the addict feels the craving when confronted with CS. Cue-exposure therapy (CET) is used to suppress the conditioned response (CR) through repeated exposure to the cues related to addictive substances, but without the unconditioned stimuli (US). Some studies (Lazev et al., 1999, Sayette et al., 2001, Tiffany et al., 2000, Bordnick et al., 2005) showed increased effects of exposure to smoking cues and cigarette availability in craving and smoking behaviour. CET has been applied in the treatment of a variety of substance addictions, including smoking (Corty & McFall, 1984, Niaura et al., 1999, Lee et al., 2004). However, the effectiveness of CET has been found to be inconsistent (Tiffany

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& Conklin, 2002) and they have therefore concluded that the treatment must be correlated with a wide variety of objects and contexts.

James, W. 1966, observed that in some perceptual learning experiments the formation of a strong association between two systems of conditioned stimuli (CS<sub>1</sub> – CS<sub>2</sub>) can block the conditioned response (CR) and modify the outcome. It's well known that a smoker becomes addicted to smoking by a variety of stimuli (objects, emotions, social contexts, etc…) and that each one possesses his own system of conditioned stimuli (CS<sub>1</sub>). On the other hand, the VR allows us to design a new system of conditioned stimuli (CS<sub>2</sub>) in an environment with not only objects and contexts, but also actions. Theoretically, these associations (CS<sub>1</sub> – CS<sub>2</sub>) might be able to change some behaviour in smokers.

Our pilot experiment strategy is comprised of a system of sensorimotor stimuli designed in a VR environment and focuses on action–exposure blocking an operant conditioning. We designed a virtual arm in an environment with different visual and auditory stimuli (smoke, white lights depicting cigarettes, ashtrays, sounds of falling water, walking, etc.). The participant is immersed in this virtual environment in which he has to search for cigarettes, grasp them, and crush them with the virtual arm. He is not only a spectator, he is a player.

The main question is if an action–exposure strategy with VR is capable of modifying craving and smoking behaviours and if any clinical evidence can be derived from the procedure. At first we planned an observation study of fifty heavy smokers to evaluate the usability of this method and to explore different variables for future studies. However, the purpose of this paper is to present our initial observations of the first sixteen participants.

**MATERIALS AND METHODS**

**Participants**

We introduced the experimental sessions into our regular program NICOT, which included physical evaluation, the prescription of pharmaceutical aids (nicotine gum and patch, Bupropion) and a three-month clinical follow-up for each participant. The participants were recruited from among those who had relapsed. They received general information on cybertherapy, a description of the experimental sessions and specific information on cybersickness. The participants agreed to provide their opinions during and at the conclusion of the experiment. They were assured that they could abandon the sessions at any time and that they were under no obligation to quit smoking.

We completed sixteen of fifty trials. The characteristics of the participants, eight men and eight women, are shown in Tables 1 and 2. They were middle-aged, heavy smokers, and extremely nicotine dependent with a high level of motivation subjectively evaluated on a scale of 1-10. Eight of the sixteen had relapsed at least five times previous to this in our program. There was no significant difference between the two groups. The status (smoker/non smoker) was determined by verbal declaration at the end of the final experimental session. The smokers continued to smoke at the level of pre-session and the non-smokers used zero cigarettes after the fourth session. The status after 4 sessions is recorded at the bottom of Tables 1 and 2.
Table 1: Characteristics of participants (Women)

<table>
<thead>
<tr>
<th>Participant</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>MEAN</th>
<th>±</th>
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<td>46</td>
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<td>43</td>
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<tr>
<td>Nb. Cig/day</td>
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<td>15</td>
<td>20</td>
<td>25</td>
<td>20</td>
<td>25</td>
<td>10</td>
<td>25</td>
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<tr>
<td>Fagerström</td>
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<td>8</td>
<td>-</td>
<td>6</td>
<td>5</td>
<td>9</td>
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<td>3</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>4</td>
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<td>3.3</td>
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<tr>
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<td>4</td>
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<td>4</td>
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<td>2</td>
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<tr>
<td>Status after 4 sessions</td>
<td>S</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>S</td>
<td>NS</td>
<td>S</td>
<td>-</td>
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</tbody>
</table>

S: Smoker  
NS: Non Smoker

Table 2: Characteristics of participants (Men)

<table>
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<th>#4</th>
<th>#5</th>
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<td>5.4</td>
</tr>
<tr>
<td>Nb. Cig/day</td>
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<td>25</td>
<td>30</td>
<td>15</td>
<td>20</td>
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<td>6</td>
<td>8</td>
<td>-</td>
<td>8.3</td>
<td>1.4</td>
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<td>Motivation</td>
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<td>10</td>
<td>7</td>
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<td>8.3</td>
<td>1.3</td>
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<td>Nb attempts</td>
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<td>16</td>
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<td>8</td>
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<td>4</td>
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<td>4</td>
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<td>-</td>
<td></td>
</tr>
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<td>Status after 4 sessions</td>
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<td>NS</td>
<td>NS</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

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**Equipment:**

The design of an arm able to move in a virtual environment enabling its hand to grasp and crush cigarettes was the product of creative professional graphics. We used programs such as XSI from Softimage and 3DS Max from Autodesk (photo 1). We then integrated our 3D work into a game engine from a well-known FPS game called Unreal Tournament 2004 (UT 2004) (photo 2). The game is set in an old castle where the subject can wander through different chambers located on multiple levels.

We hid 25 cigarettes in the castle and added some objects depicting cigarettes and smoke. Due to vertigo in the fourth subject, adjustments to the VR program were made to prevent the feeling of elevation. The hardware consisted of a Pentium IV PC with a Nvidia 7300GS graphics card. We used the eMagin Z800 head mounted display (HMD) with a head tracker. A resolution of 800 x 600 pixels was needed for the virtual display. The participants used a Logitech wireless game pad to operate the virtual arm.

**Procedures:**

The participants were required to attend a total of four sessions (twice a week for two consecutive weeks) at our clinic. We followed the protocol for reducing cybersickness outlined by the Cyberpsychology Lab UQO (Bouchard, S., 2002). Before the first session, participants had to answer a questionnaire providing information related to immersion propensity. We spent fifteen minutes teaching each subject how to manipulate the arm and position in the virtual environment. The session started only when the participant had familiarized himself with his VR surroundings. He had to find 25 cigarettes (photo 3), reach for them with the virtual arm, and crush them with its hand by pushing a command on the game pad (photo 4). The session ended when the participant had crushed all 25 cigarettes. After the first session, participants filled out two questionnaires pertaining to the state of presence and cybersickness symptoms (Bouchard, S., 2002). A recovery period of 10 to 15 minutes was given after each session. In the event that a participant abandoned the experiment, we contacted them by phone for an explanation as to why.
Results:

Most participants compared these sessions to playing a fun, user-friendly video game. They carried on a running commentary during the sessions and they felt a sense of enjoyment waging war on cigarettes. Others hesitated before crushing a cigarette and then regretted doing it. They seemed sceptical, confused and were afraid of being manipulated by an unknown technique. Ten participants (62.5%) completed the experiment. One participant abandoned after the second session because of height phobia, which we continued to treat with VR desensitization. Five participants (31.5%) dropped out after 2 or 3 sessions stating they were not ready to quit smoking. The dropout rate was within the range of the Jorenby DE et al. 1999, who reported that a mean of 34.8% of their subjects discontinued the experimental treatment (Bupropion, nicotine patch or placebo) during their study. Eight (8) participants quit smoking and the mean of smoking cigarettes (22.8 cig/day) by the 16 subjects in pre-session moved down to 12.8 cig/day. This difference is statistically significant at 0.011 with the non-parametric Wilcoxon rank test \((Z_{(16)} = 2.53, p < 0.05)\).

Adapting to the virtual environment was quick and easy, requiring minimal effort. The average time spent catching and crushing 25 cigarettes was between 20 and 40 minutes, but some completed it in 10. The participants’ profiles for specifics variables of VR exposure collected in the first session are recorded in Table 3. The immersion propensity and state of presence variables are comparable to the control values. Cybersickness could have been more frequent in the participants but the variance in the data was too high. We noticed that two results (111.4 and 125.3) specifically for disorientation were over the control maximum value (97.4). We also observed a high level of awareness in the smokers and a particular attraction for different objects and cigarettes in the VR environment. We suspected the psychoactive effect of nicotine to be a cause.

**Table 3: Specific variables to VR exposition**

<table>
<thead>
<tr>
<th></th>
<th>Control *</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immersion Propensity</td>
<td>64.1 ± 13.3</td>
<td>55.1 ± 10.0</td>
</tr>
<tr>
<td>Presence State</td>
<td>104.4 ± 18.9</td>
<td>122.3 ± 18.7</td>
</tr>
<tr>
<td>Cybersickness</td>
<td>9.8 ± 15.0</td>
<td>28.9 ± 29.5</td>
</tr>
</tbody>
</table>

* in Bouchard, S., 2002

After each session, many reported aftereffects such as flashbacks (the virtual arm, sounds, objects), revisiting the virtual environment, the need to crush cigarettes and reliving sessions in their sleep. Some participants said that they crushed their cigarettes instead of tapping them in the ashtray while smoking. One participant remarked that she often saw an ambiguous white object that gave her loving care and protected her when she had an urge to smoke. All these phenomena may have been spontaneous or may have been activated by an urge to smoke. Furthermore, two subjects categorically denied crushing cigarettes after their first session.
During their second session, they stated that they hadn’t crushed cigarettes but had instead put them in their pocket, much like a squirrel does when gathering nuts (storing).

Out of the ten subjects who completed the four sessions, eight decided to quit smoking during the course of the experiment. A follow-up one month later revealed that only one had relapsed. A cessation rate of 70.0% after one month is in the range of the Jorenby et al. (1999) double therapy (Bupropion and nicotine patch) at 66.5%. Smokers who quit found that this method was better suited to their needs and that the urge to smoke had greatly diminished.

**DISCUSSION**

Our first observation concerned the creation of an integrated sensorimotor system of conditioned stimuli in a VR environment that could be effectively imprinted onto a smoker’s brain. Goldstone, R.L., 1998, maintained that perceptual learning involves relatively long-lasting changes to an organism's perceptual system that improves its ability to respond to its environment and is caused by this environment. Imprinting may come from entire stimuli or parts or features of them. Bedford, F.L., 1993, argued that learning is much easier when the entire visual dimension can be shifted or warped to map onto the proprioceptive dimension than when unrelated visual-motor associations have to be acquired. Rumelhart et al., 1986, believed that internal representations can function as acquired feature detectors built up through environment exposure. At a more abstract level, Goldstone, R.L., 1998, reported that topological imprinting can occur when the space and the positions of patterns within the space are learned as a result of training with patterns. This implies the creation of a spatially organized visual network that may favour the formation of a strong association. Psychological manifestations experienced by the participants furnished clinical evidence of a new cognitive map of images and associative actions.

The second observation of our experiment explored the potential capacity of blocking the conditioned response (CR) with an action-exposure strategy. Both humans and animals exhibit behavioural phenomena such as "discounting" and "augmentation" (Kelly, H.H., 1973). One of the best-known cases of discounting is the cue validity effect, first reported by Wagner, A.R. et al. (1969). Rescorla-Wagner, 1972, in her learning model stated that a reinforcer can sustain only a limited amount of associative strength; therefore, simultaneously presented cues must compete with one another as the best predictor – or cause – of the outcome. Castro & Wasserman 2007 said that we are able to predict an effect on the basis of observed cues, but we are also able to predict the effects that our own actions will have on the environment. Instrumental conditioning or operant conditioning relies on the ability of organisms to learn that their own actions can produce action outcomes. "Man's first experience with causes probably came from his own behaviour: things moved because he moved them" (Skinner, 1971). The action-exposure strategy seems to have the potential of blocking a CR like smoking. Our pilot experiment might have influenced the behavioural outcome of the eight heavy smokers who quit smoking in the four experimental sessions.

The third important observation concerned the subjects who gave up or tried to get around the experiment by storing cigarettes. In perceptual learning with a “changed-response” experiment, Morgan et al., 1966, showed that if the stimulus-response (S-R) association formed the basis of the original learning, great disruption could take place when the subject was forced to change to
other responses that had never been associated with the stimuli of the learning situation. Disruption was suspected as the result of certain subjects not being ready to quit smoking.

Our pilot experiment is not conclusive enough to either analyse or generalize these results. It's a small study with few subjects observed over a short period of time. The operating procedures need to be standardized for future studies. However, these preliminary results could be an interesting avenue for research in the treatment of substance addiction.

**CONCLUSION**

A variety of sensorimotor stimuli in a VR environment seems to ease the imprinting of a new map of associative actions on the brain. This acts not only on the arm's specific movement, but also on all conditioning processes in smokers. The original conditioned response CR\(_1\) (smoking) may be blocked in some subjects who learn a new virtual conditioned response CR\(_2\) (crushing) that will help them quit smoking. As for the subjects who did not complete the experiment, disruption may have been the cause. Two subjects created a new virtual conditioned response CR\(_3\) (storing), which allowed them to keep on smoking. The action-exposure strategy seems to have the potential for blocking a conditioned response and possibly modifying craving and smoking behaviours. This approach (AE-VR) could be considered in the treatment of substance addiction.
BIBLIOGRAPHIE


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