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# Use of virtual reality technologies as an Action-Cue Exposure Therapy for truck drivers suffering from Post-Traumatic Stress Disorder

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ABSTRACT

This work describes a truck-driving simulator designed for the care of truckers suffering from post-traumatic stress disorder (PTSD). This simulator exploits a new approach using virtual reality (VR) technologies in the treatment of PTSD. Indeed, we exploit full capabilities of VR technologies to not only expose the user to the frightening stimuli but also to allow him to be active in this environment that may contain anxiety-provoking stimuli. These two aspects are supported throughout a gamification process where the game mechanics are mapped to the expected learning mechanics. Moreover, the developed simulator is fully customizable. Two truck drivers suffering from PTSD have experimented it. The intervention allowed a desensitization and a verbalization of fears associated to the past trauma.

## 1. Introduction

As related by the American Truck Association: the trucking industry is the centerpiece of the U.S. economy [1]. The 2012 Commodity Flow Survey data shows indeed that trucking carries more than seventy percent of the US freight [2]. Doing so, truck drivers do deliver 71.3% of the total weight of US freight, 71% of the market value. These observations explained why in 2013, although large trucks represent only 4 percent of all registered vehicles, they account for 9% of all the mileage traveled [3].

However, when analyzing the characteristics of the work of a trucker, several factors that may impact his psychological health, emerge. Some factors may be intrinsic while others are extrinsic to the truck driver [4,5]. The first category groups all issues having a direct link with the working environment. This includes the feeling of discomfort or even the insecurity due to ignorance of a trip, a night driving, feeling nervous because of a heavy and/or undisciplined traffic. The stress due to the weather, the breakage, the nature of the cargo (often dangerous) are also professional conditions that may affect his health [6]. Regarding extrinsic factors that may negatively impact the mental health of a trucker, one counts the remoteness of the family, physical health weakened by a lack of physical exercise, fatigue and loneliness. All this seems to create an environment conducive to accidents [7,8].

Above reasons explained why in 2013, it has been observed that large trucks represented 9 percent of vehicles involved in fatal crashes. This percentage drops to only 3 percent when one considers crashes having only injuries and/or property-damages. Two important facts have to be retained regarding vehicles crashes. First, large trucks were more likely to be involved in fatal multiple-vehicle crashes. Second, in fatal crashes, only 17% of the victims were occupants of large trucks. With these observations, it appears that most of truck drivers who had an accident are likely to face post-traumatic problems. All this explains, as suggested by Saberi et al., why the number of drivers suffering from Post-Traumatic Stress Disorder (PTSD) tends to be undervalued [9].

In addition, one can reasonably understand that most of the accidents having no material or physical injury are probably not reported. However, it is possible that some of these accidents may have heavy consequences on the psychological health of the trucker. A driver, who indeed narrowly avoids a life threatening accident, has probably faced one of his biggest fear. As a result, he may have hard times to recover from such a memory that will haunt him regularly. In such a situation, without an adequate care, it could lead to a situation of post-traumatic stress disorder.

In Quebec (a province of Canada), the CNESST [10] (the organization to which the Quebec government has entrusted the promotion of rights and obligations related to work) statistics clearly show the impact of age on the occurrence of accidents. Paradoxically, the more the trucker gets older, the more he is at risk to have an accident. This suggests that every driver is likely to have an accident in his career. Therefore every truck driver is likely to face PTSD. Considering, the personal, professional and societal consequences that are associated to

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PTSD, our research targets this need. For this, we want to exploit Virtual Reality technologies, in order to provide an Action-Cue Exposure Therapy for truck drivers suffering from Post-Traumatic Stress Disorder.

## 2. Related work

Among the countless events of life, sometimes our physical or psychological integrity is threatened. War, terrorist attacks or traffic accidents represent this kind of event that may have a major impact on someone. For such a situation, going over the details of the event in his mind and/or having poor sleep quality, are among the normal reactions that eventually decrease with time. However, in some cases, the psychological impact is so strong that the reactions do not decrease but rather increase with time. These symptoms may be anxiety, flashback, panic attack, avoidance, decrease of responsiveness to the outside world, and getting to a complete isolation. PTSD is the mental illness that characterizes such a psychological state. PTSD appears to affect 6.8% of the US population [11], whether adults or children. Because of this, PTSD is considered as a major public health problem [12]. What follows briefly reviews some approaches that have been carried out for the treatment of patients suffering from PTSD over the years. We first discuss about the rational for exposure therapy afterward we review one by one the main approaches that have been exploited.

### 2.1. Rational for exposure therapy

During manifestations of PTSD symptoms, there is intense emotional arousal. These reactions are directly linked to stimuli capable of eliciting strong emotional responses of the patient. Therefore, the treatment will have to bring the person to be able to control his emotions [13]. For this, Exposure Therapy has been created [14]. This treatment aims to reactivate the fear sensation of a patient by gradually expose him to fear-provoking stimuli and let him react and control his emotional reactions [13]. In the case of an anxiety provoked by a car crash, the stimuli can be a flipped car on the side of a road. To gradually expose the patient to stimuli that may trigger strong emotional reactions, several approaches have been exploited over the last two decades. In this group, one counts: the exposition through images or films [15], the exposition through hypnosis [16], the exposition in the real life also known as in vivo exposure [17]; as well as an exposition by the use of virtual reality technologies also known as in-virtuo exposure [18].

### 2.2. In-vivo exposure therapy

With in vivo exposure, patients are gradually exposed to situations, feelings, places, images, sounds, smells and memories related to the past traumatic event. With this exposure, the patient gradually decreases his fear of the situation. Some patients consider it as too anxiety provoking [19,20]. In our case, in vivo therapy is difficult to reproduce in the real world because the subject could lose the control of his truck due to a sudden high anxiety for example [21]. In such a condition, real life situations can be replaced by pictures, films or mental imagery as long as the media contains a fear-inducing stimulus [13]. Indirect exposure using videos or images seems to be a good alternative to in vivo exposure [15]. Patients are exposed indirectly by watching fear-inducing stimuli. One can easily realize that in such a situation, the user is not able to perform any real actions. He is only exposed to the stimuli.

### 2.3. Imaginal exposure therapy

Imaginal exposure is another form of treatment for PTSD. Patients are asked to imagine details of the traumatic event, focusing on feelings and emotions. It can be coupled with imagery re-scripting where the patient is asked to imagine reacting as he wished he had done. Good results are obtained with these treatments [22]. It shows that reaction is a key factor in a treatment. If the subject acts during a fear-inducing situation, results are better. Such results motivate our work, however as opposed to this approach we want to exploit virtual reality technologies in order to offer the user an environment that allows him to really perform all expected actions.

In some researches, in vivo and imaginal exposure are even combined into multiple weekly sessions to form what is called Prolonged Exposure Therapy (PE) [23,24]. Tuerk et al. [25] investigates 65 veterans using PE with promising results.

### 2.4. In virtuo-exposure therapy

Use of VR exposure therapy (also known as in-virtuo exposure) has proven especially useful when in vivo exposition may not be exploited. This happens when the patient may not support a real-life exposition or the situation may be difficult to reproduce live. For example, it can be hard to expose someone to a real terrorist attack. Moreover, he can be reticent to the direct sight of fear-inducing stimuli. The patient can have dangerous reactions during the exposure. In-virtuo exposure can also be valuable when imaginary exposure is inefficient (e.g. because the person is not able to properly represent the source of anxiety in his mind) [26]. Several research areas as diverse as arachnophobia, agoraphobia and obsessive compulsive disorders have shown the benefits of using an in-virtuo exposure therapy [27–29,11]. In fact, one of the major benefits of using VR technologies is the customization of the Virtual Environment (VE). It can be modeled to fit the needs of each patient and safely expose them at their own pace and closely to a specific traumatic scenario.

This is why we want to use VR technologies for the care of truckers suffering from PTSD. The main innovation of our work resides in the fact that we not only want expose the user to the frightening stimuli in a safe environment; we also want to allow him to be able to react (to be active) in this environment. We name this approach: Action-Cue Exposure Therapy (ACET). The next section presents the rational for the ACET approach.

## 3. Action-Cue Exposure Therapy: ACET

This section describes the theoretical approach of the proposed research. We first discuss about the rationale for an Action-Cue Exposure Therapy. Second we argue that having an Action-Cue Exposure Therapy allows to take full advantages of VR technologies.

### 3.1. Rationale for an Action-Cue Exposure Therapy ACET

As seen previously, in the care of PTSD there is clear rationale for a therapy approach based on exposition (CET). The goal is to bring the person to be able to control its emotional reactions to anxiety-provoking stimuli [30,13,31]. In CET, behavioral techniques are therefore exploited for a systematic desensitization by a gradual decrease of the conditional response (Pavlovian conditioning – By always preceding the food by the sound of a bell, (conditioning); the sound of this bell alone is enough to make a dog salivate (response)- [32]). In our research, we want to prioritize a behavioral approach based rather on operant conditioning principles [33]. The main response to the stimulus is then a behavior conditioned to an action. We thus speak of Action Cue Exposure Therapy (ACET). In contrast to CET, ACET seeks initially to avoid a direct exposition of the subject to traumatic stimuli. But this approach aims primarily to strengthen some passed skills, such as driving a truck. This will eventually allow the subject to rediscover the pleasure of driving. Following this step, we can indirectly expose to subject to traumatic stimuli. In this case, it is expected that the emotional response may be countered by the continuity of the behavioral response.

### 3.2. Action-Cue exposure therapy allows to take full advantages of VR technologies

As most researchers, we see VR as a scientific domain that allows one or more human users to perceive and interact in real time within an immersive and pseudo-natural digital world called VE. This VE can be a copy of reality, but also a simulation of some of its aspects, a symbolic representation of a concept or a phenomenon, or a totally imaginary world. In this sense, it appears that to perceive and to interact represent two components of the outmost importance in a VE.

Yet our analysis of different works on VR technologies to cure PTSD revealed that the full potential of VR is rarely targeted. Indeed, considering an application such as Virtual Iraq [34,35]; a simulator where soldiers could revive a series of war events; it is clear that this work has paved the way to a very innovative approach. However, the exploited simulator does not allow the patient to be fully active in the environment, it mainly delivers anxiety-provoking stimuli to the patient. In fact, this work focuses much more on the presentation of the stimuli. Being able to model the VE in order to match the characteristics of the frightening situation is a mandatory steep. However, besides the presentation of the stimuli, the interaction part is missing or remained underexploited considering the results achieved in the last decade in this domain [36–38]. With the proposed approach, since a particular attention is devoted to interaction part, it appears that it can exploit more from the VR technologies. With this new approach the VE will be dynamic and interactive [39,40] almost like in the real life. With such a VE, the patient can thus have a completely different experience for the same situation that has traumatized him in the past.

Two components are thus required to design a VE that exploits the ACET approach. These two items are i) allowing the user to be active ii) being able to render anxiety-provoking stimuli adapted to the mental state of the patient. In our case of interest, namely the care of truckers suffering from PTSD, we study these two components through the next two sections alternatively: the gamification and the customization of the truck-driving simulator.

## 4. The gamification of a truck-driving simulator

As explained previously, the ACET approach aims primarily to strengthen some passed skills such as driving a truck. The gamification process will clarify how this learning will be possible in the game. For this, we gamified the proposed rehabilitation simulator using the mapping of Learning Mechanics to Game Mechanics (LM-GM) as proposed by Arnab et al. in [41]. This model places the emphasis on the Game Mechanics (GMs), their link with Learning Mechanics (LMs) and the implementation of those links. It aims to help identifying the main features of a Serious Game (SG), by providing a list of common GMs and LMs. That leads to a better specification of the most suitable implementation of those features. To do so, we analyzed the game loop (see Fig. 2) and identified six main groups of Game Mechanics (GMs) which we associated to their respective Learning Mechanics (LMs). These GMs are reviewed in what follows.

- Movement, Simulate/Response and Realism: During the driving simulation, the player has to move in the environment, with a realistic response to its actions. The associated LMs are Exploration, Simulation and Action/Task.
- Levels, Cascading Information and Behavioral Momentum: The game is divided into sessions called Levels organized to provide Cascading Information i.e. increasing complexity in terms of information to deal with. The Behavioral Momentum is obtained through the looping over levels. The associated LM is Repetition.
- Story and Information: The story is given by the purpose of the job. Information is created around the context of such mission (load, client, etc.). The associated LMs are Guidance and Instructional.
- Tokens: Random elements affect the game (from the user perspective) that are either controlled by random sequences or the supervisor e.g. weather conditions, car crashes. No specific LM is associated to this item.
- Feedback, Rewards and Status: At the end of a level, the feedback offers to the user the assessment of his success or failure. His status is then updated (experience gained) and rewards are provided to him. The associated LMs are Feedback and Motivation.
- Design/Editing: Aside the main gameplay, designing contributes to the user's immersion and reinforce his experience by providing a sensation of ownership. The associated LM is Ownership.

All of those associations, as well as their implementation that will be discussed later, are summarized in Table 1. For more details regarding the gamification of the designed truck-driving simulator, one can refer to [42,43].

## 5. A fully customizable environment

It is known that the immersion of the user in the VE plays a leading role when it comes to address anxiety disorder through the use of VR technologies [44,26]. As various other authors, we define immersion as the capacity of the system to deliver a coherent set of stimuli that will generate for the patient the feeling of being transposed in a universe other than his physical reality. Because of this, the focus has been placed on the design of a fully customizable environment. This allows having an environment that is ideally suited to each patient. More specifically, on one hand it lets to offer the possibility if necessary to recreate a scenario that is very close to the one having traumatized the trucker. It has been demonstrated that a familiar environment containing suitable stimuli (conform to the patient's trauma) is a key factor in the treatment. On the other hand, it also allows, if necessary, creating an environment that trivializes the traumatic situation through an allegory. And of course, all the situations that may be placed between these two extremes are also feasible, for the well being of the patient.

As a result, we developed an environment editor directly integrated in a professional game engine: Unreal Engine 4 [45]. This game engine allows users to create realistic game environments with an easy to use editor. In addition, it matches characteristics highlighted by Malbos et al. [46]. They have indeed pointed out that a therapeutic treatment environment must have, among other aspects, a first person view, detailed textures, artificial intelligence, shadows, interactions and virtual body. From the work of Malbos et al.[46], we have retained the following guidelines:

- The VE must provoke emotions. The patient has to be immersed in the VE and has to be aware of the consequences of his actions in the environment.
- The VE must offer flexible scenarios. Every patient needs different amount of time to control his anxiety.
- The VE must adapt the stimuli of scenarios to the patient. Every patient has different reactions to elements like weather, traffic or car crash.

To meet these requirements, the environment must be fully customizable. The environment cannot be fixed and unique: it has to suit the patient profile. Furthermore, the practitioner must be able to quickly modify the environment without having any technical skills related to computer (like being a game designer or programmer).

Based on this, we have developed the proposed simulator in order to be suitable to multiple profiles of patient. More particularly, proposed customizations aim at targeting the factors that do affect the mental health of a trucker. What follows summarizes the main points that have served for such a customization. For more details regarding this customization, one can refer to [47,43].

**Fig. 1.** Rendering of the same location under different conditions.

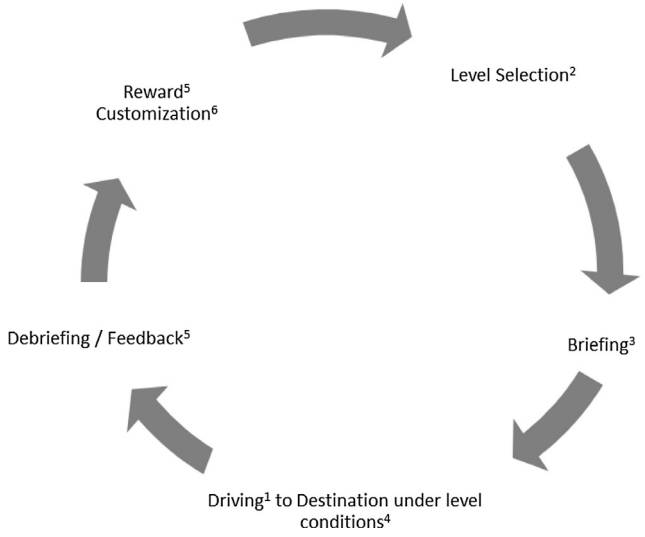


**Fig. 2.** Game loop explicited with the LM-GM model.

### 5.1. Customization of the roads and the surroundings

For a driver, the road describes a central piece of his task. Hence, the road has been an element of a particular interest in our customization. We have designed and implemented a full road generator for this simulator.

A road is basically a Bezier curve. Initially, it consists of two points, movable on demand in an empty 3D map. This allows creating a straight road (a line-segment). Then, the user is able to add points on the line to create a natural curve. Road textures can be changed (tarmac, dirt, pavement with high quality graphics) as well as the width and the slope. Road intersections can be created by selecting the roads. To increase the credibility of the environment, intersections are not necessarily right-angled but may be deformed depending on the roads positions. Directional arrows, traffic lights and stop signs are also automatically created.

Once a road is rendered, many elements can be placed automatically or manually in order to simuate a more natural environment. These elements may be, but are not limited to:

- Road signs. They are a decisive element that will help to remind the current environment (a highway for example). In our case, road signs of the province of Quebec are used but other country signs can be easily imported. Size and written directions can be modified if needed.
- Street lights, vegetation, barriers, parking lots, bridges, ground markings, roadworks.
- Automatic creation of paths for the artificial intelligence. (see Fig. 3)

Besides these elements, a considerable time saving is possible through the automatic generation of the roadsides immediate environment. Buildings, parking lots, fields and vegetation are automatically and randomly generated on selected roads (see Fig. 4). Several types of neighborhood are thus available.

**Table 1**
Game and learning mechanics of the simulator, based on the *LM-GM* model

| Game mechanic | Learning mechanic | Implementation |
|---|---|---|
| Movement, Simulate/Response and Realism[(1)] | Explore, Simulation and Action/Task | Immersion through a HMD and a *racing wheel* |
| Levels, Cascading Information and Behavioral Momentum[(2)] | Repetition | Levels |
| Story and Information[(3)] | Guidance and Instructional | Radio messages & Level conditions (job given) |
| Tokens[(4)] | | World events: Weather, Day Time, Car Crashes |
| Feedback, Rewards and Status[(5)] | Feedback and Motivation | Level change, Pop-up and Truck customization |
| Design/Editing (6) | Ownership | Customization of the truck |

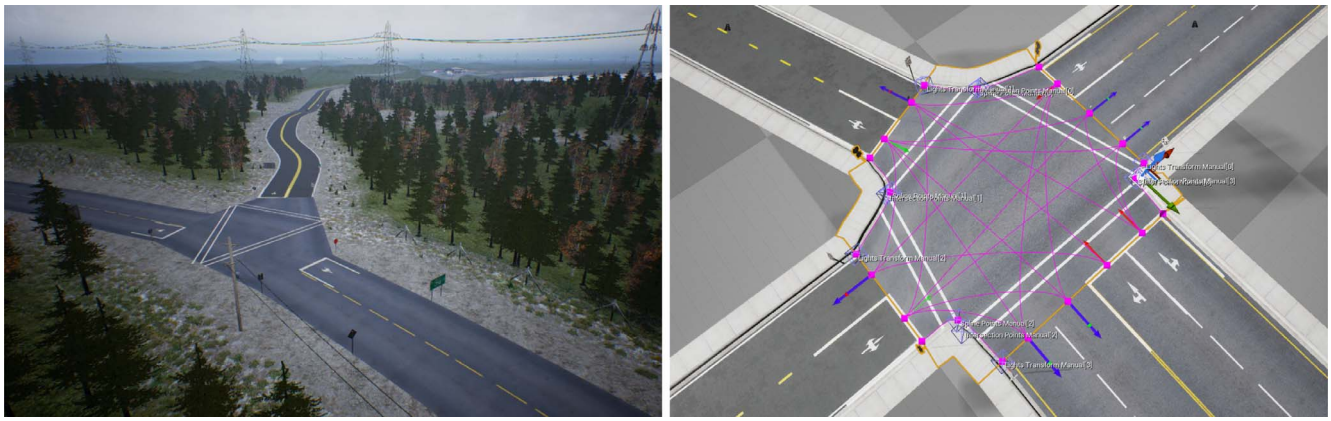

**Fig. 3.** Example of generated roads.

To ensure good performance of the system, a background composed of real pictures can be placed. The pictures can represent famous buildings of the city, like Montreal, Quebec or any patient's city. It increases the immersion of the user because he recognizes familiar places.

### 5.2. Designing of anxiety-provoking stimuli according to the traumatic scenario

Concerning stimuli, imperative to exposure therapy, Taylor et al. [48] classified some stressful situations for drivers. Among them, the fear of the vehicle crash or the loss of control due to weather conditions are the main fears recorded.

- *Vehicle crash:* We include in the proposed simulator, a tool to randomly create vehicle crash scenarios. These crashes involve other vehicles but not the patient's truck because ACET does not directly involve the patient in the cause of his trauma. The supervisor can choose the severity of the crash (based on the mental state of the patient) that will be shown on the road (involving motorcycles, trucks, animals and emergency vehicles). The crash can be randomly placed or not. The crash severity is chosen in a menu before the game starts.
- *Loss of control:* Knowing that the loss of control of a vehicle happens quite often during the winter, we also provide a tool to control the weather and the time of the day. On any environment, the supervisor can easily change the time of the day (sunrise, noon, afternoon) and the weather (rainy, stormy, snowy, windy, foggy) in a menu or directly in the running game. Fig. 1 shows different conditions for the same area.

### 5.3. Customization of the truck

It is known that truckers have a great attachment to their vehicles.

**Fig. 4.** Example of generated neighbourhoods.

Because of this, we are able to edit a truck in order to reflect the vision of the trucker. This will help bringing the patient to express his attachment to his truck. High graphics quality interior and sounds are used to improve the immersion. The patient is able to choose a well-known truck and change the design of it, either its outside and inside parts. Materials of the seats or the dashboard can be changed as well as the color of the truck. His choices are then associated to his profile. The trucker can also activate some common truck functions like wipers, blinkers, horn and lights.

### 5.4. Artificial Intelligence

To engage the user, in the virtual scenario presented through the game, a generic Artificial Intelligence (AI) has been developed. Cars, trucks and motorcycles appear randomly at a chosen frequency and density on the roads. They follow the road lanes, generated at the creation of the roads. Cars adapt their speed to the road and the road signs. In the same way, they do respect stop signs and traffic lights. Up to thirty vehicles can be spawned at the same time on the map, without decreasing the speed of the game. Another module, that allows to randomly spawn animals crossing the road or high speed vehicle overtaking the patient's truck is also provided.

The genericity of the AI permits not only to spawn cars or trucks in the traffic but also spawn trains, planes or ships.

### 5.5. Delivery missions

Trailers can be attached to trucks in the game. This means the driver can take a delivery mission. For example, a specific type of trailer spawns in a chosen industrial area and has to be delivered in another industrial area. As the driver have mirrors and can also turn his head, thanks to a Head Mounted Display, to see out of the left window, maneuvers can be achieved as in the real life.

## 6. Materials exploited to support the immersion of the user

Different devices are exploited in order to propose an immersive but low-cost truck-driving simulator. The immersive aspects is supported through mainly: a "Head Mounted Display" for the visual modality and a set having a racing wheel, a gearbox and pedals equipped with haptic feedbacks to control the vehicle. (see Fig. 5).

- Head Mounted Display (HMD): Instead of working with a VR Headset, we developed our project using a Sony HMZ-T2/T3 [49] providing a better overall visual quality. To compensate the absence of Head-Tracking on this headset (compared to other headsets such as the Oculus Rift), we developed an interface with the NaturalPoint TrackIR 5 head-tracking system [50]. The combination of those technologies offers the user the ability to turn his head in order to fully appreciate the interior of its truck. This is particularly interesting, since it may reveal meaningful details about the dashboard meters and buttons. It also allows looking out the window and in the mirrors, providing a freedom of movement and a feeling of realism.
- A set having a racing wheel, a gearbox and pedals: The Logitech G27 3 Driving Force GT Racing Wheel is used to drive the truck. The mechanical feedback system integrated with the steering wheel reacts to turns, shocks and speed in a realistic way, emulating the real sensations of a wheel. Both automatic sequential and manual modes are also available due to the lever and the buttons dedicated. A few other buttons offer more controls over base functionalities (such as light management, windscreen wiper, and trailer attachment) highlighted by visual indicators on the control panel and a change in the behavior of the vehicle. The auditory modality is also exploited since the truck sounds are reproduced in the VE.

**Fig. 5.** Current setup of the system. A user experimenting the game, the HMD on his head and the wheel in hands.

## 7. Case study

We report in this section the use of this simulator with two former truckers suffering from post-traumatic stress disorder following their truck accident. This study was conducted within the Futaie therapy center. The goal were to desensitize the subject with the use of VR technologies exploiting the approach based on the "Action Cue Exposure Therapy" (ACET). The context of the experience and the followed protocol are described.

### 7.1. Participants

Two truckers who have an accident took part to this study. Since their accidents, both participants patient were inactive, inhibited by the fear of truck driving: they were continuously anxious and depressed. We refer them as: Participant A ($P_A$) and Participant B ($P_B$).

Participant A, aged fifty, was a truck driver for twenty years, he said that he always had fun driving a truck. In the spring of 2013, when he had to bring a trailer truck in the garage of his employer, he had a burst tire. Despite his efforts, his truck overturned and caught fire; he collapsed. When he regained consciousness, he heard a motorist shouting to evacuate for fear of an explosion. He managed to extricate himself from his truck. He is followed by a psychiatrist and treated with medication.

Participant B, aged thirty-six, had seventeen years of experience. For its last thirteen years he had the same employer, he used to drive short and long distances. During the summer 2015, within an excellent weather condition, while turning to the left at 35 mph, he lost the control of his truck and ended up in a 50-foot ravine on the edge of a lake. He did not lose consciousness but had the impression of dying. At the stop of his truck, he found himself: head on the pedals and feet on the passenger seat.

### 7.2. Protocol

The study took place over eight sessions. The first two sessions are devoted to pre-exposure to the truck by an allegory. We used a flying carpet to avoid excessive anxiety reaction to the truck symbol. To control the carpet, we use the same interfaces (helmet, steering wheel). At the third session, we find the first exposure to a truck. The patient

ends up in a parking lot where several types of trucks are stationed at reasonable distances. The patient can move at its own speed in that environment, allowing its progressive exposure and skills recovering. At this time the patient is asked to choose its preferred model of truck from a selection of well-known trucks. Session four is dedicated to driving a truck. At this stage the driver is free to move in the environment. No disruption related to road conditions is included in the scenario. Here the objective is to allow the trucker to eventually recover the pleasure of driving. At the fifth session, the trucker is tasked a mission where he has to drive till the position of a trailer. Afterward, he has to attach the trailer to his truck and has drive to a final destination. After that, the patient has to perform a maneuver to park the trailer at a specified location in reverse gear. During this session various events starting from small road without traffic, to driving on highways with traffic are presented. Moreover, several weather conditions (rain, snow, darkness) are also rendered. At the sixth session, the patient is ultimately, but indirectly, exposed to the trauma through a burning truck on the roadside. At the seventh and eighth session, the content is similar to the fourth one. Here the goal is to allow the patient to work again with the mechanisms related to the driving.

### 7.3. Pre-experimental evaluation

($P_A$) has an excellent cooperation, good intellectual abilities. His anxiety level is very high and constant. The symptoms of PTSD assessed by the PCL-5 questionnaire are significantly elevated with a total of 57/80. We also note a depressive picture with a strong sense of guilt, helplessness, fatigue and exhaustion, feeling of being burned and the emergence of black idea. The patient demonstrated excellent treatment motivation and openness to a possibility to return to work, in the case of an improvement of his general condition.

($P_B$) is well oriented in the three spheres; his speech is well structured. He reports concerns about constant back pain and especially the cervical region. Since the accident he experiences short-term memory losses. He often forgets commonplace things. The psychic tension is very high, his mind is always distracted; being unable to concentrate, he no longer has the same vigilance. He constantly saw the film of the accident and he feels a lump in his throat. He does not sleep at night but does naps during the day. He does not feel able to drive a truck.

### 7.4. Observations and discussion

#### 7.4.1. Case of ($P_A$)

The cybersickness was very intense at the first session because the subject seemed to be hanging in the air. We have corrected the situation by lengthening the carpet forward to provide reference points and similarity to the front of a truck. The use of allegory as a flying carpet in the first 2 sessions appears to have facilitated the adaptation to driving RV. There is no direct confrontation with the image of the truck. This probably explains why there was no anxious climax. There is no resistance to ride in a truck at the 3rd meeting. Rather, the subject has himself chosen his truck and it is fitted with enthusiasm despite he had expressed the will to never drive. The subject tended to brake very early at intersections. This is explained by the fact that he failed to brake at an intersection before his accident. During the sessions, the average stress levels of the subject is estimated at 4–5 of 10. There was a slight increase when added exposure to rain, snow or night driving. The rapid immersion in the VE was visible and significant. He listens to the radio sometimes. The subject revives, virtually, with the pleasure of driving a truck. While driving in the simulator, the subject regains his driving skills, performances and concentration. He strives to do well. The use of a single cab simulator is sufficient for good exposure and immersion. No need for a trailer.

The subject failed in the cabin trailer coupling operation. His reaction was a loss of control and great anxiety: rapid movements, loss of concentration, impulsiveness. The subject reported a sense of failure, lack of performance and loss of control. We note an attempt to avoid the stretch of road that represented the place where his accident occurred.

The subject speaks little. It seems isolated in his cabin and very focused on driving. The subject easily dissociated by immersing himself in his truck cabin on the road. With the exposition to a burning truck, the reaction of the subject is invasive. He refuses to stop at the scene of the accident, but he agrees to continue driving his truck. This exposition triggers a sudden and intense verbalization. He starts talking about truck accidents he witnessed, the dangers of the road, etc. After that session, the subject reported that he reacted like a trucker. His cabin has literally become a counseling office. He needed to share his stress and fears as truckers used to do in their radio communications. The subject lived a verbalization therapy according to the rites of the truck community. The day after the exposure to the accident, as he lunched at a restaurant, he reports having realized the dangers of the traffic and driving a truck. The hazards of driving a truck become aware, he has a new contact with the reality. He realized he would not be able to get back into this working environment. At that point, it seems that the subject has lost its identification with the truckers community. After this, the subject agrees to the proposal to initiate a career change process. With the contact of a real truck, the subject founds the machine very big compared to himself. He expressed the desire to return to a suitable working environment.

**Synthesis** To face the residual hazard of driving a tractor-trailer, the subject will develop defensive strategies. These include: a merger with the machine, its strength, its power, its individuality, a denial of fear. The accident is a breach of such a reality. This result is an identity conflict, pervasive fear, a failure feeling, a power loss and an impaired of his self-esteem.

The intervention allowed desensitization, a verbalization of fears and anxiety with the method used in his work community. The virtual cabin has become a place of therapy. The danger awareness has undermined its defensive strategies. This allowed the patient to progress in the grieving process by accepting the status of an *ordinary: non-hero* worker.

#### 7.4.2. Case of ($P_B$)

Due to a very high level of stress (90%) and a sudden panic reaction, we interrupted the first session after ten minutes. As, the subject showed a great motivation, we were able to resume. To prepare the subject to the driving there were two sessions with the allegory of the flying carpet. At the end of the first session, the subject estimated that his stress level was about 55%. After the second session, the subject spontaneously expresses that he is proud of himself and of his performances. He also reports great fatigue after the sessions. He becomes aware of his stress level especially when driving. From session three to five, the level of stress when driving the truck stabilized at 55%. At home, he estimates that his stress level drops to 35%.

At the session 6, changing the scheduling of the sessions gave the impression of a return to work, the subject found the conduct less stressful. At this session we carried out an indirect exposure to a truck overturn in a curve. The subject decided to not stop and continues the driving. He reported a headache but anxiety did not rise. At that time, he began to recount memories of previous accidents. He reports that his level of anxiety drops to 35% with an improvement in his behavior. He feels less nervous, and reports having less flash of his accident. However, he also noticed an increase in his stress level to 55% when exposed to rain or wind. After the session, the subject estimates that he has the impression that something has happened.

Although the game offers three colors of trucks: red, blue or beige. For the first sessions, the player always chose the beige truck. It was only at session 7 that he chose to drive the red truck and the blue one at the last two sessions. At session 7, he reports that his cybersickness is significantly high. This may be explained that the fact that the subject keeps turning to check the condition of the trailer. Sessions 8 and 9 revealed a stabilization of the stress level of driving at 35%. The subject

also reported a feeling of recovering his skills with a good return of his reflexes. One week after cybertherapy, the stress level remained at 35% and PCL-5 decreased to 25/80. The reduction in symptoms mainly affects cluster E, which has decreased from 14/24 to 6/24. The main changes include irritable behaviors, hyper-vigilance, startle reactions, concentration and sleep disturbance. At that time, the subject is willing to try a road test with a monitor.

**Evolution of the subject** The subject carried out four road tests in September 2016. He had a blockage with a very high level of anxiety when he had to take the truck with the trailer but he managed to control himself and have completed his training. He is now back to work with his former employer. He drives dump trucks and trailers. He traveled a long way to fetch forestry machinery. He said that he was very happy and pleased with him. He noted a residual fear in the detours to the left and he often looks in his mirror to reassure himself. Overall, he estimated that his stress level has markedly decreased. He has recovered his sleep, he no longer suffers from headache, nausea and sensations of dizziness. The PCL-5 test has decreased to 10/80. He no longer takes medication.

## 8. Conclusion

To address the need of truckers suffering from post-traumatic stress disorder, we report here the exploitation of a new approach in using VR technologies. The main innovation of this work resides in the fact that we not only want to expose the user to the frightening stimuli in a safe environment; we also want to allow him to be able to react (to be active) in this VE. We name this approach: Action-Cue Exposure Therapy (ACET). From this approach, we designed an adapted truck-driving simulator that has two main characteristics. First, the game mechanics are associated to the skills that we want the trucker to recover. As a result by using the proposed simulator, the user will eventually retrieve the feeling he used to have prior his trauma. Second, this simulator is fully customizable. It allows rendering anxiety-provoking stimuli adapted to the mental state of the patient. We reported the use of this simulator with two truckers suffering from PTSD.

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