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RISK-HUNTING TRAINING IN INTERACTIVE VIRTUAL ENVIRONMENTS

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Safety is an everlasting concern in construction environment, when an accident happen it is rarely harmless. To raise awareness and train workers to safety procedures, training centers have risk-hunting courses where real-life equipment is set up in an incorrect way. Trainee can safely observe these environments and is supposed to point at risk situations. In this paper, we propose a risk-hunting course in VR (Virtual Reality). With VR, we can put the trainee in a full construction environment with potentially dangerous hazards without engaging his safety. Contrary to others risk-hunting courses, we have designed a virtual environment with interactions to emphasize the importance of learning to correct the errors. First, instead of only having to spot the errors, we make the trainee act to fix the error. We want the act of fixing an error to become a reflex action. The second way we use interaction is by adding consequences to not fixing an error. For example, not fixing an error in a scaffolding may make it collapse later. This rely on scriptwriting the virtual environment to add causality on specific actions, our goal is to educate the trainee on the dramatic consequences that can arise when errors are not corrected.

Keywords: Safety, Training, Virtual Reality, BIM, Interaction.

INTRODUCTION

Architectural, Engineering, Construction and Owner-operated (AECO) Industry in France, a sector highly exposed to occupational accidents

The AECO industry is the most accident-prone sector (CNAMTS 2016) in France. In 2014, 145 construction employees (excluding temporary workers) died while working in France. The construction industry accounts for 8.6% of employees (INRS 2014) and recorded 16.3% of "accidents with work stoppage" and 26% of deadly accidents. As for the causes of accidents, manual handling is by far the most challenged category, accounting for more than half of all work stoppages (Assurance Maladie 2016) with a rate of up to 53%. Follows falls on the same level with 13%, falls from height with 12%, and the use of hand tools with 9%.

An economist approach to the question shows that their cost, globalized with that of occupational diseases, would amount to 1.3% of the national wealth (Azkenazy 2004), this cost is equivalent to ten additional days of paid annual leave per employee per year. These few figures illustrate the very dangerous nature of the sector and lead to an interest in the problem of accident prevention in construction.

Vinci Construction France

Large companies such as Vinci Construction France have for many years been conducting a comprehensive prevention policy with the "zero accidents" plan in order to reduce their frequency rates $(TF) = (\text{number of accidents in first payment} / \text{hours worked}) \times 1,000,000$.

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However, the complexity and the diversity of the operating modes, the methods, the architectures as well as the contraction of the deadlines of realization have an impact (Cramif 2000) on the level of security when carrying out the works.

Training, essential lever

Various reasons can help to explain the difficulties that prevention poses in this sector of activity: risk factors' origins are human, technical, organizational, material and are often interdependent. Statistics show that workers benefiting from reduced support in the company, including posted workers, foreigners, temporary or apprentices, are most prone to workplace accidents. As an example, mention can be made of the INRS report (INRS 2014) which stipulates that accident victims of foreign origin (non-European) are three times more numerous in the building and civil engineering sector than in other sectors, the same is true for European foreign employees.

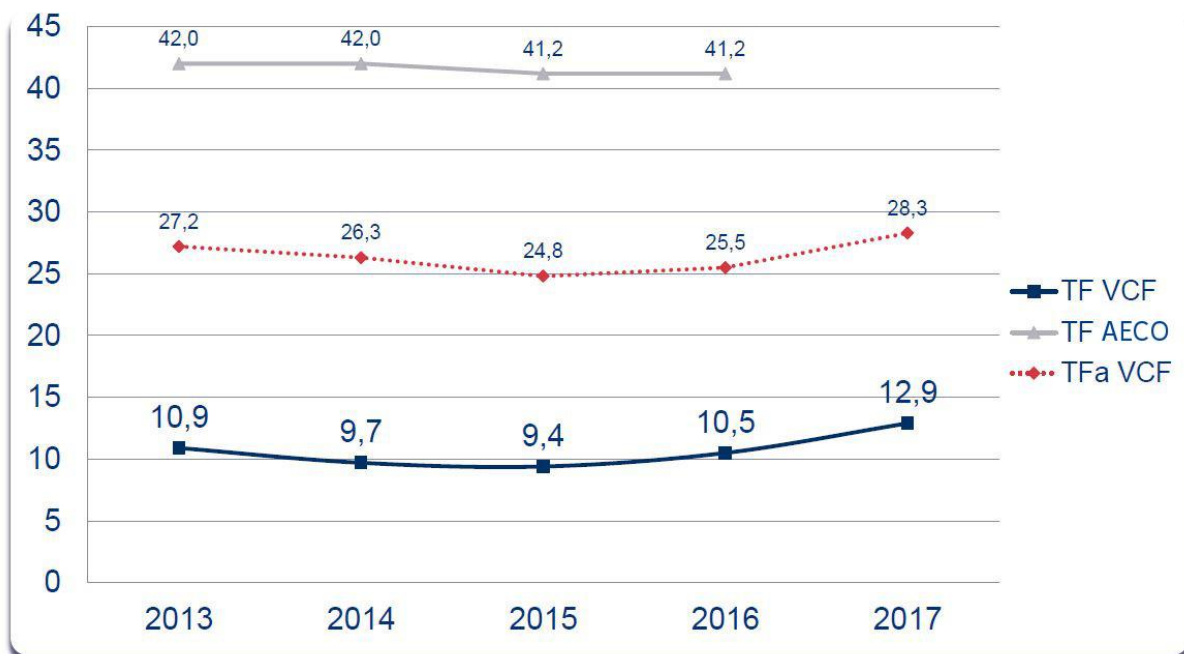


Figure 1: Evolution of frequency rate (TF) = (number of accidents in first settlement / hours worked) x 1,000,000.

These statistics highlight the lack of training and experience of these categories of workers, especially for foreigners, but also the lack of support for temporary workers, who change their job and work environment regularly. Even in large groups such as Vinci, which for many years has been conducting a comprehensive prevention policy with the "0 accident" plan, the difference in frequency rates between employees and temporary workers is still worrying.

However, a higher level of training leads to safer behavior (OPPBTP 2017) during the construction phase.

One of the difficulties encountered in the management of training is related to temporary workers who do not always benefit from the same level of information and knowledge related to the materials and methods of construction specific to the site on which they intervene.

Recent studies demonstrate the benefits of virtual reality training (Ho and Dzung 2010) compared to traditional training methods. But the costs involved are still high (Gao and Gonzales and Yui 2017) in the case of virtual reality. Moreover, in both cases, the training is sequenced and does not allow the real situation. However, each construction project is unique,

the work environment has a considerable impact on the perception of risk and therefore on the behavior of employees.

For example: a driver knows that he has to stop at a stop sign, he marks the stop and can leave if the way seems clear and safe. But if a tree, hiding a car, obstructs his field of vision, the latter would necessarily be affected but not his perception of risk.

The arrival of the BIM, a working process commonly used in the construction industry, makes it possible to obtain a virtual double of the act of building.

Goal

The purpose of this study is to present a virtual reality training scenario generation method that allows the trainee to be immersed in the unique configuration of the site he / she will intervene.

CONTEXT

Overview

Traditional prevention of work-related musculoskeletal risks is oriented along two almost independent axes: the technical axis and the human axis. The limits of these approaches are currently recognized by ergonomists and some prevention professionals who are trying to create a third path together. It is a matter of reconciling technical and human orientations based on the understanding of the work activity and designing, in particular, risk prevention training programs that develop the ability of all prevention actors on their own work activity and their power of action on the technical or organizational aspects of work (Teiger 2002)

Several reasons (Choudry and Fang 2008) explain the risky behavior of the workers: the lack of knowledge of the safety rules, the lack of respect of these rules, a non-conducive environment such as high productivity targets, psychological factors, the pride of "hard leather" in male environments such as construction, lack of training, organization of the site and a sequencing of the tasks to be performed that do not take into account the needs of the workstation.

Traditional training in risk prevention / Training in virtual reality

Virtual reality provides a relevant response to the act of training to perform tasks without dangers, train many people at lower costs from different locations (Lourdeaux 2001), understand abstract concepts or absolve from the language barrier (written or oral), and put into practice.

In the classic risk hunting paths in the field of construction, trainees are assessed on their ability to identify risks on reduced scenes and reduced tasks. They cannot be allowed to correct the problem or simulate their work on these insecure scenes, their lives may depend on it. This technology also offers interesting aspects for the trainer: scenarios can be implemented by the system itself, recording and review of sessions, trainee assisted evaluation, possibility of acting (Verna 2017) on the level of difficulty of the exercise to assess the impact of cognitive load ...

We also note that traditional training does not allow trainees to adapt to a changing environment (Huard 2008) so immersion into a risk hunt in reality virtual can enrich learning.

In the particular case of risk prevention, the reflex to danger is the expected result. According to the work of JB Watson, the reflex can be conditioned by the senses and participates in the acquisition of knowledge (Beauchesne 1985) in humans. We agree with Sutherland's (1965) view that "the ultimate (virtual reality) device would be an environment in which the computer

could control the existence of objects (and our interaction with them). We could sit on a chair in this environment. Handcuffs in this environment would be really coercive, and a bullet would be fatal. " The 5 senses can therefore be solicited (Fuchs 2006) simultaneously, which increases the interest and commitment of the participant (Cherrett et al 2009) in his training thus improving the acquisition of knowledge.

The limits of VR in relation to Real Education today are of a technical nature related to the use of a new technology: technical and professional skills of the developer, acceptability of interaction techniques by trainees not accustomed to video games (training approaching a serious game), the orientation can be disrupted by the reduction of the field of vision, the movements whose latency can be problematic.

We also remember the motion sickness that can disrupt immersion in the virtual environment.

Support a time in virtual reality

The current limitations of the technology, weaknesses in the design approach, such as usability issues and the cumbersomeness of the resulting applications are not to be overlooked as sources of potential problems (Burkhardt 2003), both for the transfer aspects between virtual situations and the real world and for the aspects of user assistance, in order to avoid difficulties use do not induce cognitive overload that is harmful to learning.

Lack of return

During our research on the benefits that virtual reality can bring compared to traditional training methods, we have been faced with the problem of lack of existing studies. The return of the experiments carried out does not make it possible to establish a concrete result .

If the finding seems clear about the benefits of this technology during the training, its interest in the long term (Sacks and Perlman and Barak 2013) remains to be proven.

DESIGN OF THE RISK-HUNTING COURSE

Interactive Environment

To display and interact with the virtual environment, we can use different kind of devices with varying degree of immersion. These devices include a screen mouse and keyboard, a head mounted display (HMD) or a CAVE. We decided to use a HMD (HTC Vive) in or case because these kinds of system can be easily transported and deployed in training centers while allowing a good degree of immersion. The trainee wears a headset that cover his field of view and show him the virtual environment and can move in a limited play-area by physically walking. The trainee also has two controllers to interact with the environment in a few different ways:

Walking and teleportation is used to navigate in the environment. The trainee can physically move in the play-area to navigate through the virtual environment. The play-area being much smaller than the virtual environment, a second way of navigating through teleportation is implemented. By pointing with the left controller, the user is able to teleport (which move the play-area location in the virtual environment) to reach unattainable locations.

Use and grab objects. Some object in the scene are usable and interacting with them can trigger certain effects (e.g. interacting with a closed door will open it). To interact with an object, the trainee has to point it with the left controller and press the interact button. This method allows to interact with an object without having to physically reach it. Also, some object in the scene are grabbable. These objects can be grabbed by pointing them with the right controller and hold the grab button.

Taking instruction. The trainee can get instruction from his superior in form of dialog pop-up.

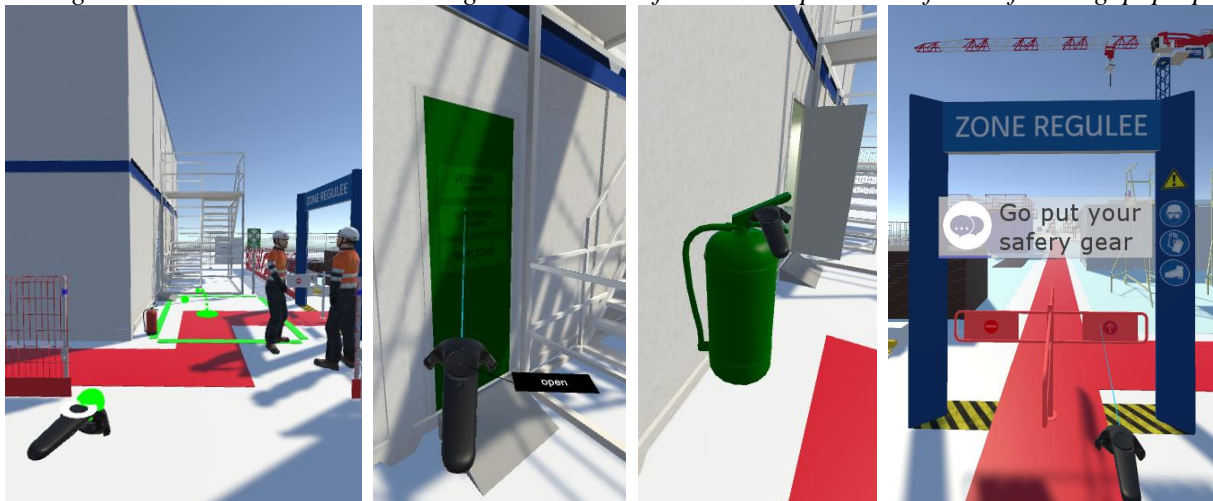


Figure2: Examples of the different ways to interact with the environment. From left to right: teleporting to a new location, remotely interacting with an object, grabbing an object and getting instructions

Accustoming to VR

Before letting the users go to the full construction environment, we make them first go through a smaller environment. In this first environment, the trainee is tasked to find and wear all mandatory safety gear. This scene ends by going through the turnstile that leads to the construction site. Any attempt to go through the turnstile without the necessary safety gears is denied.

In the point of view of pedagogy, this scene makes sure that the trainee has the good habit of wearing all the necessary safety equipment and does not forget anything.

In terms of VR training, this scene is used as an acclimatization time for the trainee to learn how the system works. This small scene contains a few instances of the main interactions for the trainee to play with. The trainee can learn to navigate in the environments, take instruction (which tells him to wear the safety equipment) and interact with objects. For the trainer, this scene is used to assess the capabilities of the trainee in virtual environments and help him get used to the setup if necessary. After this accustoming phase, the trainee can proceed to the second scene which is the construction site.

Introducing Errors

For the construction site, we defined for this risk-hunting course a list of types of errors we wanted to include. One example of a type of error is the misplacement of the fixings of a PTE platform (cf. Figure 3). For each type of error, we then procedurally try to find every possible way to create an instance of the type of error. In the case of our example, this means iterating over all the PTE platform fixings and try to find for each of them an incorrect location. With all these possible error instances, we are then able to randomly select which error to use for each trainee. This selection can either be completely random, or made around areas of interest to if we want to define a specific path for the trainee.

Scriptwriting

Scriptwriting is used at two levels to manage the risk-hunting course: global-guidance and error-scriptwriting. Global-guidance is tasked with guiding the trainee in the environment. A scenario is written to list the events (or chain of events) that the trainee must do to fix the errors. Since the virtual environment encompasses a whole construction site and we want the trainee to be exposed to certain errors we inserted in specific areas of the construction site, we need a way

to direct the attention of the trainee to these specific areas. This is achieved by giving instructions to inspect or do something in specific area to force the trainee to go near error instances. These instructions are written in the scenario and are given to the trainee automatically during the simulation.

Error-scriptwriting allow to define how errors must be corrected and what consequences will happen if they are not corrected. Each type of error has a scenario that describe how this error can change over time depending on the action of the trainee. Figure 2 gives a simplified example of such scenario. This error-scriptwriting is used to improve the pedagogy of the training by allowing us to describe two important elements: what action(s) must be done to fully correct the error and what might happen if the error is not corrected.

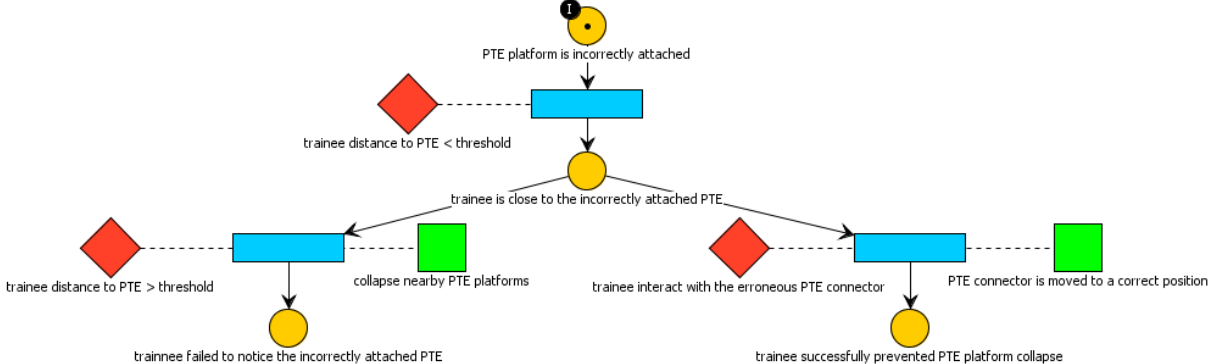


Figure 3: Example of an error-scriptwriting scenario for the misplacement of fixings of PTE plat. Yellow circle represents the possible states (with the initial state marked with a 1). Blue rectangle represents transitions between states with red diamonds being condition to be able to trigger the transition and green squares being consequences of the transition.



Figure 3: Example of misplacement of fixings of PTE platform in the virtual environment. On the left, one fixing is misplaced (circled in red) and placed above an opening. On the right, this is what the trainee will see if he walks away from the PTE platform if he doesn't signal the misplacement of the fixing (This correspond to the bottom left state in Figure 2).

Feedback After the Training

Scriptwriting

USER STUDY

A user study will be performed on construction worker to assess the effectiveness of this form of training. In this user study, the VR training will be used in conjunction of standard training in the context of standard training days organized by the company. The goal of the user study is to evaluate the acceptability of VR training for construction worker as well as evaluate the short and long-lasting effects of the training. The acceptability of VR-training is evaluated with questionnaires (standards) for perceived-workload, presence and sickness after the training. Efficiency of the training is evaluated with a knowledge test performed before the training, after the training and one month after the training.

CONCLUSIONS

In this paper, we presented a risk-hunting course in VR that highlight interactivity and scriptwriting of the virtual environment to improve the involvement of the trainee. We also presented the methodology we will use to evaluate the acceptability and effectiveness of this method of training.

For this training, we use the same scenario for every trainee. In future work, we want to have multiple scenarios that induce varying levels of stress and danger by adding more errors and changing the conditions (e.g. the weather). These scenarios could be used by the trainer to tailor the experience of each trainee depending of his past performances. Furthermore, we want to add real-time analysis of the performances of the trainee while he is in the virtual environment to adapt it to his behaviour. We could monitor the error the trainee makes to introduce other instances of the same error to accentuate the training toward the trainee weaknesses.

Another area of improvement would be collaborative risk-hunting, this would improve the fidelity and logistics of the training. In real-life work condition, workers are not alone in a construction site. Having a collaborative environment for the training would allow a more faithful experience. Furthermore, current trainings are organized for a whole group of trainees. In this context, it is difficult to include a new part in the training that must be done and managed individually. This is one of the reason that makes the introduction of VR in training centre difficult and collaborative training where multiple people could be trained simultaneously could alleviate this problem.

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