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Virtual Environment for Effective Training

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Resumen.

*L*os entornos virtuales (VEs) ofrecen diversas ventajas para el entrenamiento. Por ejemplo, en relación a costos un VE es reutilizable a un relativo bajo costo, además aquí los materiales no se gastan o rompen; en algunos casos los VEs evitan la necesidad de instructores o hacen su participación menos indispensable, de tal forma que los instructores podrían ayudar a más aprendices; también pueden prevenir la transportación cuando aprendices e instructores se encuentran geográficamente distantes. Otras de sus ventajas están relacionadas con la seguridad, misma que está garantizada para los usuarios, especialmente cuando se trata de situaciones o materiales de alto riesgo. Esto aunado a que ofrecen las facilidades de cualquier sistema computacional como grabar la sesión de aprendizaje, el análisis automático de la información o guardar registros de desempeño, entre otros. En base a una recopilación literaria, en este documento se describen algunas peculiaridades que presentan los VEs para el entrenamiento y se comenta sobre algunos estudios empíricos en referencia a su efectividad.

Palabras clave. *Entornos virtuales, sistema de entrenamiento, realidad virtual.*

Abstract.

Virtual environments (VEs) offer a number of advantages for training. For example, related to costs, a VE is reusable at a relative low cost; on a VE materials do not wear out or break. In some cases, VE avoids the need of an instructor or makes his/her participation less mandatory, thus leaving the instructors free to help his/her apprentices. VEs can also prevent transportation issues when apprentices and instructors are geographically distant. Other advantages are related to security, which is granted to users, especially for risky materials or situations. In addition, VEs offer the same benefits other computer systems may have, like recording learning sessions, automatic data analysis or storing performance records, among other functions. Based on a literature review, this paper discusses VEs' training uses and some empirical studies about its effectiveness.

Keywords. *Virtual environments, training systems, virtual reality.*

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1. Introduction

Virtual reality (VR) is the computer generated display of either a real or an imaginary scenario, with the purpose of giving the users the feeling of "being there" in an environment other than the one they actually are, and to interact with that environment [1]. VR allows people to expand the users' perception of the real world that is otherwise impossible. Two of its main advantages are the spatial visualization and three-dimensional interaction capabilities provided [2]. VR is a promising alternative for hands on training, especially in risky situations or in scenarios with limited or expensive access. This offers helpful options for both the trainees and the trainers.

Virtual environments are a powerful tool that can be enhanced for training with immersive or haptic devices, distance learning, intelligent virtual tutoring, and/or collaborative resources. Along with computer facilities like data storing and/or its in time analysis, the training uses for VEs allow people:

a) to learn new skills,

b) to improve the ones they have, or

c) to recover skills, e.g. in the case of rehabilitation.

Beyond VRs motivational impact, apprentices may feel less pressured than in a real life training scenario, for example, when treating a patient. In VEs, trainees have the opportunity to understand the consequences of their choices without suffering them.

In spite of the aforementioned advantages, an important question arises about the effectiveness of the VEs for the trainees' acquisition or improvement of skills in comparison with traditional methods. In this paper, some characteristics of the VEs from the training point of view and a literature review regarding its pedagogical effectiveness are discussed.

2. Virtual Environments for Training: Overview

Computers have always been linked to learning; with teaching purposes, tutorials, training and simulator applications have been created. Recently, 3D virtual environments allow students to navigate through and interact with the virtual world to carry out certain tasks that bring the visual characteristic to the computer training scenario that supports both:

- learning by watching, and
- learning by doing;

two techniques that facilitate tutoring and that are broadly used to train people in diverse domains. In such a way that training has become one of the significant application areas for VEs. Under this viewpoint, some of its characteristics are here remarked.

2.1. Desktop, Augmented and Immersive Virtual Reality

The users' degree of immersion in a VE is directly dependant on the user-computer interaction device. This degree of immersion is typically classified as desktop-based, augmented reality (AR) and immersive VR. The purpose, scope of a training program, and the system's cost are probably the main influence determining the desired degree of trainee immersion in the environment.

Desktop-based VEs, while less immersive for the user, can be considered relatively cheap, and therefore easier to spread. This makes them appropriate for multiuser or massive training environments see Figure 1.

In desktop VR, the user can interact with both, the real and the virtual world at the same time; this can be helpful for example, when the trainer is physically next to the trainees. Its significance is confirmed by the many developed training desktop-based VEs, e.g. [3-6]; among which, the presented in [6]used by the US Army for training soldiers in foreign cultures, is an example of how elaborate desktop-based virtual environments can be.

Figure. 1. A desktop virtual environment with head tracker

Augmented reality incorporates computer-generated information into the real world, supplementing it with virtual objects that appear to coexist in the same space. Traditionally, AR is mainly achieved through display devices, although it is not restricted to the sense of sight [7], it can apply to other senses such as hearing, touching and smelling; the number of mixed approaches is many; an extensive survey can be found in [7].

In AR, haptic devices, that give tactile feedback to the user, have become an integral component of numerous training simulation systems. The purpose of haptic rendering in training environments is the realistic replication of real-world forces relevant to a particular task [8]. A good example of mixed display and haptic techniques in AR, is the elaborated one [9]that simulates out-doors for single and team rowing, in this approach, authors modeled the team behavior with the purpose of training a single user to synchronize his/her inter-rower as if training within a team.

In immersive VEs, the user can interact exclusively with the virtual world, see Figure 2. In spite of the cost of immersive VEs, there is evidence that in some cases they might be cost-effective as stated in the [10]study of developed systems in the US by the Army Research Institute, where dismounted soldiers are trained via immersive VEs.

An interesting semi-immersive VE for training is the one presented in [11], employed to train astronauts in life sciences experiments by using a Virtual GloveboX. The user introduces his/her hands in the gloves that are in one side of it, which give to the user tactile feedback, while a high resolution environment is displayed on the top of the box.

Figure. 2. The CAVE, an immersive virtual environment

2.2. Avatars for Users and Agents that Tutor the Training Session

Other important element in a VE is the avatars. For the user, his/her graphical representation in the computer environment is called avatar. In single user systems, the avatar will be the means for interacting with the virtual world [12], while in a multiuser situation the users' avatars will also help them perceive each other [13].

Avatars can be as simple as a pointer or as complicated as in humanoid representations. According to Salem [14], the avatars can be categorized and characterized in three groups:

1) abstract, represented by cartoon or animated characters with limited or predefined actions;

2) realistic with high level of realism, which imply high cost in technology and hardware resources; and

3) naturalistic, those with a low-level detail approach can be characterized as humanoid-like avatars that can display some basic human actions or expressions.

In VEs, having physical body representation can be very helpful for aiding conversation training and understanding the virtual space [15]; the avatars add nonverbal communication to the VE such as when gazing or pointing at virtual objects. The three different approaches to transmit nonverbal behavior from the users' avatar to the VE according to [13] are:

1) directly controlled with sensors attached to the user;

2) user-guided, when the user guides the avatar; and

3) semi-autonomous, where the avatar has an internal state that depends on its goals and its environment, and this state is modified by the user.

Avatars can also be the representation of an intelligent agent within the VE. Software agents' characteristics according to [16]are:

a) software that does not need supervision and/or human control to realize its task, thus they are autonomous;

b) agents may be able to cooperate with users or with other agents; and,

c) software agents can learn, that is, they can change its behavior as a result of its cooperation.

Probably because of its many factors and complexity, at some point, multiagent systems have been proposed to manage training virtual scenarios e.g. [17, 18], in which the agents act to take care of different structure units of the environment such as the world, the expert or the trainee.

In training VEs, a virtual tutor might be represented by an agent's avatar; which brings a third important factor in training scenarios: the tutoring.

2.3. Tutoring the Training Session

Human tutors in training VEs have access to all the conveniences of a computer and can be used to record every trainee intervention and in turn elaborate statistics in time. Another convenience the computer system allows is distance learning with synchronous and asynchronous communication between the tutor and the trainee. This can avoid transportation issues for both of them and could be helpful in scheduling. Moreover, the human tutor can be aided by a virtual tutor, or when necessary, being substitute by one.

In the Computer Aided Intelligent Instruction (CAI) paradigm, there is a growing interest on research focusing on Intelligent Virtual Environments (IVE). VEs may incorporate, in different degrees, characteristics of learning environments through an Intelligent Tutoring Systems (ITS).

The traditional architecture for the ITS consist of four modules [19]: the expert or domain module, containing the information to be taught to the learner; the student module, which maintains individualized information of the students; the tutoring module, which provides a model of the teaching process; and the interactions with the learner controlled by the communication module.

Within an ITS, the intelligence skills generally fall into a pedagogical virtual agents (PVA) [20] to engage and motivate students along their learning process. Virtual pedagogical tutors may help the trainee in different ways, for example:

- by showing procedures like in a videotape;
- guiding him/her, giving advices or tips; or
- supervising the trainee, and intervening when he/she makes a mistake.

The virtual tutor can interact by simply sending text messages, but its embodied causes the "persona effect" [21], the students' positive perception of the learning experience related to a lifelike character in the interactive learning environment.

A number of projects aiming to use of VR for education and training supported by embodied PVAs have been developed, some of the most significant projects are from more than a decade ago [22], all of them with different capabilities and scopes. One of the most well-known animated virtual tutors is Steve (stands for Soar Training Expert for Virtual Environments), developed by the USC Information Sciences Institute's CARTE and first used to train cadets in naval tasks such as operating the engines aboard US Navy surface ships [22]. Steve was designed to interact with students in networked immersive VEs. A survey of animated pedagogical agents can be found in [23].

There are a number of international standards for component-based architectures in the field of educational software such as the SCORM (Sharable Content Object Reference Model, www.adlnet.org) which is the integration of several approaches and is recognized as an international standard for e-learning applications. Although, according to [18], the special characteristics and needs of educational software based on VEs are not contemplated on these standards, they´re mainly oriented towards Web-based e-learning courses. In their paper, de Antonio et al. proposed an interesting architecture for training VEs, based on the ITS architecture and the multiagent paradigm.

2.4. Collaborative Virtual Environments

As mentioned, VR technology´s intention is to provide users with the feeling of "being there" [1] thus from a shared virtual reality environment it is expected that the users may get the co-presence feeling, that is, "being there together" and interacting with other users [24]. The co-presence feeling is influenced by many factors related to the used technology, such as bandwidth or the input/output devices fidelity, and also with factors related to the users' avatars, like their capabilities of nonverbal communication, their possibility to manipulate objects and to ease of navigation, avatar appearance variableness, or the users' ability to control the characteristics of the graphical environment, among others [24].

Collaborative Virtual Environments (CVEs) are virtual worlds shared by participants across a computer network. CVEs offer to training scenarios some aspects of social interaction not supported by other technologies, like videoconferencing. This is done by presenting a space that brings remote people and remote objects together into a spatial and social proximity with better representation of attention through orientation, gaze and gesture [25], and where users are likely to be engaged in interaction with the virtual world and with other inhabitants through verbal and nonverbal channels [26].

In this context, Marks et al. [27]remarked the importance of training, for surgery and other medical procedures that are always performed, as a team, not only with technical skills but with non-technical ones such as communication, teamwork, leadership and decision making [28]. They developed a system to enhance surgical teamwork training with nonverbal communication.

Computer Supported Collaborative Learning (CSCL) is focused on the use of technology as a mediational tool within collaborative methods of instruction [29]. Besides, CVEs put in the opportunity for the Collaborative Learning paradigm, that is, learning from peers or virtual training partners. Thus, CVE´s characteristics make it a proper platform for knowledge construction, concurrent with the socio-constructivist theory [30]. 3D CVEs represent a proper tool for training in spatial as well as socio-technical tasks such as in coordinated situations like rescue operations or enterprise logistic.

3. How effective are VEs for training

In contrast to education which intends to teach concepts and perspectives, the training´s aim is to teach the details of a subject, while it is usually linked to the work field. Training refers to the acquisition of knowledge, skills, and aptitudes due to the teaching of practical skills and knowledge related to specific useful competencies, while training means to guide, coach or instruct. Therefore, accordingly to the skills to be acquired, improved or recovered, the VE should provide effectiveness.

Effective training in VEs should allow for the apprentices to apply what they have learned from the virtual to the real world. The transfer of learning from a VE to the real world could be the best way to prove how effective it is for training, although not easy to monitor [31].

Virtual environments, as similar to the real world as they can be, do not always present or represent the same conditions as real life, in such a way that knowledge has to be transferred. For example, some problems Knerr [10] described in immersive VEs for training in this regard are:

- some locomotion problems because of the immersive equipment; and,
- the lack of touch feedback;

due to these technical reasons some activities cannot be performed using simulators exactly like in real life.

According to literature on transfer of knowledge, in a very succinct abstraction, the two opposite types are: the low road transfer, which corresponds to an automatic transfer of skills learned by repetition; and, the high road transfer which consists in extracting knowledge in order to set it in a particular context or connect it with something that is already known in another context. Extended information can be found in Bossard et al [31], where they described transfer of knowledge and transfer of training under different theoretical standpoints and in regarding to VEs, along with a criterion for evaluating VE effectiveness.

In rehabilitation, a special type of training where the patient tries to recover his/her skills, a number of empirical studies in transfer of knowledge have been conducted, while in these cases the transfer can be directly observed in the patient [32]. According to [33] a rehabilitation program is expected to be similar to a real world situation in both terms of stimulus and response elements, and the cognitive strategy that are expected to be employed by the trainee [33]. They distinguished the steps of the procedure as: "task elements", that is, the sensory and motor elements of a task, and "organizational set", the cognitive processing demands of a task. It can be said that the transfer of knowledge that corresponds to motor rehabilitation goes through a low road transfer, while intellectual disabilities might better need a high road transfer.

One of the most common purposes in training is that for the apprentice to learn a *procedure*, a sequence of operational steps that must be repeated every time the task is performed. In this regard, Gerbaud et al. [34], who developed an authoring platform for training in VEs for desktop and immersive virtual scenarios, conducted a study on training efficiency, using their platform in a desktop-based VE. Gerbaud, et al. [34], described the trainee's learning of a procedure as: *passing knowledge from a conscious to an automatic processing of the information and storing it in the long term memory.* According to their results on 12 participants, the VE effectively helps individuals to learn a new procedure, however as they pointed out, they did not explored if the procedural knowledge could be transferred to the real world.

Concerning the transfer, Rose et al. conducted a couple of experiments [35] to prove the transfer of knowledge from the virtual to the real world. Their results showed that there was no significant difference in the transfer of knowledge between those who practiced in the real world to those who practiced in the computer for a motor task and for a motor task with a cognitive process. On a latter, more complete study, the only significant difference Rose et al. [32] found, was that the real task performance after training in a VE was less affected by concurrently performed interference tasks compared to the real task performance after training in the real world, this in terms of the cognitive load characteristics of virtual training; thus virtual training was equivalent or better than real training on a simple sensorimotor task.

In relation to *sensorimotor skills*, the use of haptic devices within a simulator is growing for a wide scope of medical application; in this context, Morris et al. [8] conducted a study to establish the trainees' skill improvement by comparing haptic training, visual training, and visuohaptic training. They found that the combination of visual and haptic training is more effective than either of them alone, nothing new according to pedagogies, but they also found that solely haptic training is inferior to solely visual training although the task was aimed to improve sensorimotor skills.

A very important factor in many training skills programs, the transfer of *spatial abilities* training has been reported as positive with almost no exceptions on empirical studies [31]. Dünser et al. [2] conducted one of the few large-scale studies in VEs, to investigate the effectiveness of augmented reality. They considered the spatial ability as *being able to mentally represent and manipulate visual-spatial information.* In their study, Dünser et al. [2]compared augmented reality to desktop-based VR, finding not clear evidence on the effectiveness of augmented reality as a spatial ability training tool. Although they argued that traditional spatial ability measurements probably do not cover all skills that are used when working in 3-D spaces.

In this same type of spatial abilities training, but comparing immersive to desktop virtual environments, according to Knerr [10]who conducted a review study regarding VEs' effectiveness in immersive virtual simulations for training dismounted soldiers and leaders in different situations, states that although the research evidence indicates that difference in training effectiveness between immersive and desktop systems is likely small, the immersive systems are more effective, particularly when the training is for *spatially-oriented tasks,* the tasks that require *spatial abilities*.

As mentioned, the Knerr [10] study´s aim was to collect evidence through literature, regarding effectiveness of virtual training in complex skills such as cognitive and decision making; this last is worth to mention that can be trained even if some physical tasks cannot be performed in the situation. The study also evaluated individual and collective training. Knerr [10] found that research consistently indicated that for *individual training*, virtual simulations can be effective, although not necessarily more effective than the real world. Regarding *collective training* effectiveness, the small amount of data due to the difficult and highly resource intensive to do such evaluations conducted to an inconclusive conclusion.

From a very different perspective, the effectiveness of the *emotional arousal* in a virtual environment seems to be affected somehow when the trainees play videogames [36], this could be important when required during the training. For example, when the trainee has to make decisions regarding saving lives like firefighters; or as explained in [10], trainees may not take virtual training seriously because they are similar to video games.

Nevertheless, apprentices seem to agree on enjoying VEs with a conveyed positive impact. Furthermore, the trainees' perception is usually that they improve their skills by using them [10, 37, 38].

4. Discussion

Even though there are a considerable number of studies using VE for training; most of them are presented from a usability point of view. Few are empirical studies of VE as a means of an effective training resource. Moreover, these studies are frequently conducted with a small number of subjects and the different approaches further dwindle that number; also, they rarely compare results with real world situations.

Virtual environments for training are a promising field for development, they provide cost-effective, safe and offer computer caveats compared to real world training. Although, in spite of their advantages for training uses and a number of related research papers, to our knowledge there is no evidence that in terms of the trainees' skills acquisition or improvement, VEs are more effective than traditional training methods, although there is no evidence neither the other way around, that is, that VEs are less effective than traditional methods.

VEs have proved to a certain extent their effectiveness in training situations, but there is still open issues in different aspects, such as how effective they are for collective training, the effects in training of the video-game players, the impact in the trainee while training for activities that can not be performed in the VE exactly the same as in real life. Also, the need of large scale studies is a recurring subject in the VEs for training research literature.

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