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VIRTUAL REALITY AND ITS INFLUENCE ON TRAINING AND EDUCATION - LITERATURE REVIEW

Sergo Martirosov, Pavel Kopecek

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Abstract

This paper presents a robust literature review on the subject of Virtual Reality and its use in training and educational systems. Firstly, the beginnings of Virtual Reality are presented, then, advantages and disadvantages of virtual reality environments are described. Various characteristics of Virtual Reality are highlighted, which have positive or negative influence on learning or training ability of individuals. It is shown how various organizations could benefit from using virtual reality in their daily activities. Such aspect as sense of presence is also described, which has tremendous effect on how subjects perceive information in virtual world.

Keywords: Virtual Reality; Sense of Presence; Training; Education

1. Introduction

Previous research on this new technology is very helpful as it shows potential benefits and answers many questions, thus allowing to continue new studies based on the accumulated knowledge. Nowadays, Virtual Reality (VR) technology is used in various areas for various purposes. It is used in training, education, psychology, etc. Studies carried out in this field suggest that training in virtual environments can replace the hours spent in the real world. This comes very handy when training in real environments is impossible due to risk or cost. Although this technology is still in its infancy, it is confidently gaining momentum and in the near future many people will be dealing with VR on a frequent basis, be it watching movies in VR, playing games or improving skills for their profession.

The first traces of VR came from the world of science fiction. Stanley G. Weinbaum's 1935 short story "Pygmalion's Spectacles" is recognized as one of the first works of science fiction that explores VR. It describes a google-based VR system with holographic recording of fictional experiences including smell and touch [1]. Furthermore, if we go back to the early 1950s, it was the time when Morton Heilig developed the Sensorama, a multisensory simulator with wind and scent production, vibratory sensation and 3D display [2][3].

Fig. 1. Morton Heilig's Sensorama

It was an arcade-style theatre cabinet that could simulate all the senses, not just sight and sound. It included stereo speakers, stereoscopic 3D display, fans, vibrating chair and smell generators, that would allow nearly full immersion inside the short films that Morton Heilig edited himself. Next Heilig's invention was the Telesphere Mask in 1960, which was the first example of a head-mounted display. The headset provided stereoscopic 3D and wide vision with stereo sound but was non-interactive and without motion tracking. In 1987 Jaron Lanier, founder of the visual programming lab through his company developed a range of VR devices, which include the Dataglove and the EyePhone head mounted display. These inventions led to major breakthroughs in developments in this area.

Around that time, in 1968, Ivan Sutherland, a leader in computer graphics developed the "Sword of Damocles", one of the first Head Mounted Displays (HMDs), which overlaid computer graphics onto the real world, today known as augmented/mixed reality systems [2][3].

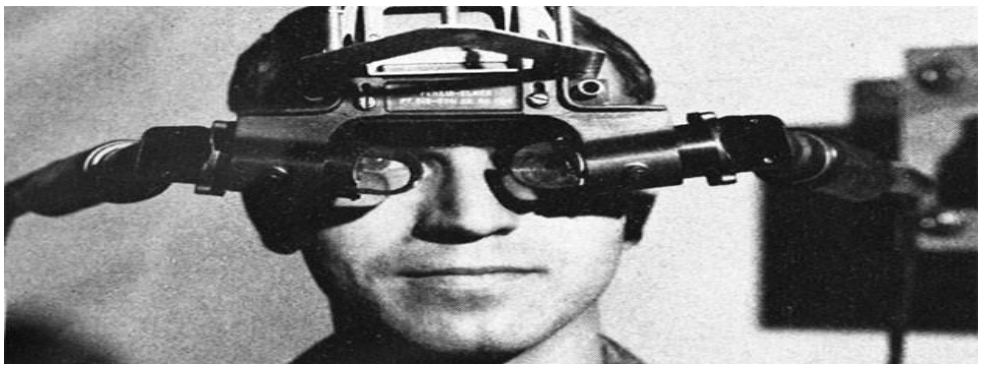

Fig. 2. The Sword of Damocles by Ivan Sutherland

NASA also had big influence on the evolution of VR technology as they worked on developing HMDs for their astronauts [3]. Throughout 1990s, we began to see VR devices to which the public had access. In 1993, SEGA announced the Sega VR headset for the Sega Genesis Console, which prototype glasses supported head tracking, stereo sound and LCD screens in the visor. Next was Nintendo Virtual Boy in 1995, a 3D gaming console that was promised to be the first ever-portable console that would display true 3D graphics. Despite low prices, it was a commercial failure due to lack of colors in graphics and lack of software support. As to the modern times, in 2010, the first Oculus Rift prototype saw the light, in 2014, Sony announced PlayStation VR, a VR headset for PlayStation 4 video game console, and Google announced Cardboard, a do-it-yourself stereoscopic viewer for smartphones. In 2015, HTC and Valve Corporation announced the VR headset with controllers.

2. Virtual Reality and Augmented Reality, the Difference

There is also another technology called Augmented Reality (AR), which is not the same as VR. The difference between those is that AR simulates artificial objects in the real environment, while VR creates a simulated environment to inhabit. VR and AR technology can be categorized as immersive VR, non-immersive VR, AR and mixed reality [4].

Both technologies have great potential in almost every industry, and each of them has different objectives. Although in some cases they can be used for the same cause/idea, the results will always be different, for example, assembly of objects can be shown with both technologies, but in different ways. Both will bring benefits if used as intended.

Fig. 3. Virtual Reality vs Augmented Reality

In immersive VR, the real world is completely occluded from the field of view and the user has a stronger feeling of presence in that virtual environment [4]. Examples of immersive VR are Oculus Rift and HTC Vive. In non-immersive VR, the user remains aware that they are viewing a virtual environment [4]. The examples of non-immersive VR systems are Samsung Gear VR and Google Cardboard. In AR, the virtual objects are like holograms, transparent in the real world in daylight, whereas in mixed reality, virtual images appear solid to the user in daylight [4]. Examples of AR are Meta and DAQRI. Examples of mixed reality are Microsoft HoloLens and Magic Leap. The integration of these technologies in different practices (i.e., clinical practice) and commercial success is dependent on various variables, which are: affordability, flexibility, wear ability, usability, immersion, mobility and vision [4][5]. VR and AR have the potential to enhance the learning environment in comparison to traditional learning. It is mentioned that 3D learning can increase learner's motivation/engagement, improve spatial knowledge representation, improve contextualization of learning and develop superior technical skills [6].

3. Virtual Reality and Sense of Presence

In the modern time VR, technology became very popular and is used in many different areas such as entertainment, military, healthcare, education, engineering etc. VR is a simulated environment that is created with computer technology and presented to the user in such a way, that user starts to feel like in real environment. A Simulation is a model of a real world where user has the ability to interact with the environment [7]. Simulations are helpful and useful as they provide realistic context in which individuals can explore, experiment and see immediate results as they create models of their own or try theories on the modelled concept [8]. Depending on the amount of senses simulated in VR, such as vision, hearing, touch, balance, even smell, the immersion level in the artificial world can vary.

Thanks to modern technological advance of computer hardware and software, it became possible to incorporate 3D VR in innovative applications of teaching, training, and learning [9][10][11]. Virtual environment or virtual world is a computer generated 3D representation of real or fictional environments. A user can interact in such an environment independently in the same pace, one would experience events in the real world [12]. VR has the ability to support realistic and immersive simulation and enables transfer of taught skills in VR into real contexts as well as provide multi-user, embodied and interactive active learning [13]. VR is believed to be a promising tool for training and complex problem solving, which requires weighing multiple variables and situational decision making [13][14][15][16].

Sense of presence is defined as "a state of consciousness", the psychological sense of being in the virtual environment [17][18][19][20][21]. It is noted by various authors that sense of presence reduces social distance between learners and improves skill acquisition and knowledge transfer by permitting multiple perspectives and situated performance [16][20][22][23]. It was noted that sense of presence in virtual learning environments increases learner's motivation and engagement in learning process and potentially learning outcomes, by enabling focused and realistic interactions with learning materials and activities [24][25][26].

A similar concept related to sense of presence is immersion – degree of "the subjective impression that one is participating in a comprehensive, realistic experience" and "the semi-voluntary experience of being transported into an alternate context for an extended duration" [15][27]. Previous research suggests that higher levels of immersion are associated with higher levels of presence [20][28][29]. The psychological perception of being inside a virtual world is known as presence [30]. Among many factors affecting user is feeling of presence, one is the content of the virtual world [31]. Immersive experience can be created via the sensory and environmental fidelity in 3D virtual environment, engagement with virtual objects and activities, and emotional experience activated through realistic scenarios in virtual world [16]. VR has been implemented as a promising learning tool both for formal and informal learning contexts in a variety of educational activities [11][32]. It was also reported that immersive VR could provide a virtual environment to simulate teaching challenges and thus act as a pedagogical tool for the collaborative/cooperative teaching/training program [33].

It has been noted that haptic feedback increases the sense of presence in VEs [34]. Haptic feedback is usually described as incorporating both kinesthetic (coming from muscles, joints and tendons) and tactile (coming from nerve receptors in the skin) information [35][36][37]. Haptic feedback can be very useful and have positive effect on task performance. For instance, it is said that teleoperators benefit from haptic feedback when manipulating remote objects [38][39]. Various studies have been conducted within collaborative virtual environments (CVE) to find out how haptic feedback influences performance. In one study a person was asked to hand over an object to another person within a CVE, which resulted in faster task completion, higher sense of presence and participant's belief in superiority of such actions, compared to those without haptic feedback [40][41]. Similar study that also used CVE, where two people collaboratively had to move a virtual ring along a virtual wire without touching a wire, showed that performance was significantly better using haptic feedback and sense of presence was increased as well [42][43][44]. Lastly, another study within a CVE in which two participants had to lift a virtual box together, suggests that haptic feedback evokes a greater sense of co-presence [45].

VR is characterized with representational fidelity, learner interaction, support of psychological sense of presence, immersion and multi-user environment for embodied interactions [6]. Prior studies note that immersive VR learning environment also enhances situated learning through simulation of realistic contexts and providing contextualized learning activities [46][47][48], thus improving performance transfer from learning environment to the real-world setting [49][50]. Nowadays flight simulators are used widely both for entertainment and training purposes, as they provide realistic environments to the extent that flight training hours can be replaced by corresponding simulator hours [51]. Several unique affordances of an immersive VR learning environment include: (I) virtual agents/avatars that act like real personalized and interactive learning partners that sometimes cannot be easily arranged in a real-world, (II) unlimited variations of 3D VR environments, and (III) possibility to transfer sensory representations to improve virtual learning actions [16][46].

4. Virtual Reality in Training and Education

VR simulations prove to be effective for not only educational purposes but also in situations, where human lives can be at risk or it could be hard and costly to check with a high precision, weather some changes are worthwhile to introduce to the real environment.

Interactivity is the most fundamental aspect in learning. It is mentioned that both, providing a learning environment and interaction with PCs may promote a better understanding of things [52]. Despite many studies in this area, there is still controversy about the real effects of VR on learning and cognition, but preliminary results indicate that the use of VR can increase learning performance [53], facilitate usability and enhance interaction [54], help to reconstruct and navigate through non-existent environments [55], help disabled learners with knowledge accessibility [56], etc. Serious games tend to be used often in formal education and with sufficient support are shown to be highly motivational and effective in learning complex tasks [57][58].

VR Technology can be of great use for emergency service personnel such as police, ambulance, fire fighters and army, as they have to be prepared for various operations at all times, thus continuous training is crucial for their success and security. But training in real environment is sometimes impossible, due to cost or complexity and the good alternative that comes handy is virtual training environment, which allows training for such complex collaborative tasks [59][60]. Thus, if the situation does not predispose for real life training practice due to danger, cost or effort, emergency service personnel can profit from virtual training to train for scenarios in real environment [61]. VR is also widely used in ergonomic applications, where workplaces are constructed virtually with the help of simulator softwares such as Tecnomatix Jack or DELMIA5 [62], than they can analyzed to make specific changes in the real workplace environment. Often VR training is the only option that is possible [63]. Some studies suggest that virtual training environments can be used successfully for training specific skills, such as spatial perception, route learning or the reactions in certain emergency situations [61][64][65][66]. There is also evidence that 3D presentation of visual information in virtual environment promotes better collaborative decision-making compared to 2D presentation [67].

Virtual training environments (VTEs) keep learners motivated and engaged in learning process [68] and have also been proven to be very useful in pedagogical contexts [69]. VTEs allow wide variety of learning styles and support collaborative knowledge building and reflective thinking [69] as well as experiential learning [70]. To enhance the effects of training, adequate instructions can be adapted to pre-training, during-training and post-training phase [71]. Some authors suggest debriefings during and/or after a training session, where individuals reflect on the training, to foster transfer of such complex team tasks [72]. It is also mentioned that virtual team performance resembles team performance in reality [73]. Team performance is dependent on whether procedures are established within a team, how conflicts are resolved and if collaboration occurs [73].

Many authors highlight the need for realistic virtual training, where training simulation holds information overload and pressure during an operation, especially when the training is meant for crisis management [74]. It is important for the

emotional state to be invoked during training and it should be as close to emotional state trainees would confront during and actual operation as possible, because of the strong effect of emotions on decision-making, learning and problem-solving [74]. Similar research suggests that virtual training for action forces such as military or fire fighters should provide first-person experiences and situated learning without time for conscious thoughts, but with the possibility of gaining knowledge [63]. The levels of immersion or presence in the virtual environment seem to be crucial for the development of first-person experiences and the knowledge gained is then "direct, personal, subjective and often tacit" and can be transferred to the real world [75]. It is noted that first-person perspective can improve learning in virtual environment [76]. In addition, it is suggested that mental representations acquired in a VTE might be similar or close to representations of real objects [64]. Experiences that individuals build in virtual environments can then become recallable and used successfully in the real world [77]. Some authors mention that in order to maximize the transfer of skills from virtual training to reality, the context of the virtual training task should be as close and similar to the task in reality as possible [78]. In addition, structuring virtual learning according to psychological factors along with fidelity to real equipment plays big role in knowledge transfer [79]. As virtual simulations or games allow exploration of realistic scenarios, learning and performance can be enhanced [72]. There is a promising potential of VTEs in educational curriculum [80].

It is important to note that assessing the level of relevance and value of training to trainees to find out the usefulness of training content to them is crucial [81], as this kind of information can help predict the transfer of knowledge and the impact of training on job performance [82]. Learning measures alone cannot be used to show whether gained knowledge will be applied, but a positive attitude towards the training makes it more probable that transfer will be successful [82]. If trainees accept training and see personal relevance for their job, they will have higher motivation to learn [83].

One of the uses of VR can be helping those with autism to lessen social anxiety and frustration and improve academic and social skills. Individuals with autism suffer impairment in social functions which leads to difficulties in social interactions, communication and emotion recognition [84][85]. Despite their good academic performance, social communication barrier can lead to frustration [85][86] and this in turn can worsen academic performance due to low self-esteem, even though their intellectual abilities are average or above that [87]. VR can be used for social training and provide safe and unlimited contexts to practice social scenarios that are most commonly encountered in our everyday life [88][89][90] and as a result, social anxiety can be reduced [91]. Additionally, it is noted that computer technology is often highly motivating and rewarding for those suffering with ASD (Autism Spectrum Disorder) and especially children with HFA (High Functioning Autism) [92]. Various studies suggest that VR environments can help individuals with autism disorders improve social problem solving and social understanding (i. e., knowing when to initiate conversation, what other person feels, choosing appropriate seat) [93][94][95].

The fact that VR reality systems can allow users to explore immersive 3D environments from any location at any time, could have a profound impact on science education [96]. VR allows exploration of hidden phenomena, distant locations and manipulation of otherwise immutable objects [97]. For instance, VR gives the possibility for medical students to explore delicate internal organs that would otherwise require cadaver (corpse) dissection [98]. VR can be a promising replacement to cadaver dissection for learning anatomy and practicing surgical procedures [99]. Direct manipulation of objects in virtual environment may promote development of "embodied", multi-modal mental representations of represented objects [100]. Embodied learning allows students to practice via simulations or mental imagery when there is no physical opportunity [100]. The ability to imagine and mentally manipulate anatomical structures is a crucial skill that medical students must have [101]. VR and computer models represent a good alternative for medical students and other professionals to practice their skills when access to patients or cadavers is limited [102]. It is also noted that to create a realistic and complex simulation/serious game with interactive objects requires some methodology and as the size and complexity of a game/simulation increases, it's becoming harder to control the environment and objects, thus a methodology is required to steadily construct a 3D Virtual World[103].

Many games have been developed using 3D images with which users need to interact in order to learn certain tasks. Interaction and immersion are the key elements when it comes to making learning process more enjoyable. 3D animations can be used to teach students various procedures and mechanisms for carrying out specific tasks [104]. Furthermore, some VR environments can support multiple user collaboration/cooperation, where students learn together and from each other [105]. This is a good way to increase their motivation for studying. It was noted, that text-based learning content often leads to boredom and can prevent students from understanding the subject [106]. It is also noted that in many different contexts video is a more effective form of learning compared to books [107].

Student motivation is vital as it has a direct influence on his/her desire and dedication to accomplish specific task [108]. Motivation is a major cognitive factor influencing learning and thus the better-motivated students can learn with higher efficiency [109]. There is a research suggesting that 3D full immersive VR Reality Learning Environments (VRLE) will increase learner's interest and motivation towards learning process more compared to 2D animated environments [110].

It has been argued by some authors that emotions play big role in learning. Some suggest that different emotional states induce different kinds of thinking [111], and others mention that a slight positive mood effects thinking in a positive

way as well, thus leading towards greater creativity and flexibility in problem solving [112]. Thanks to today's knowledge and technologies, VR environments can be created and filled with various interesting elements, making it motivative and fun for students to explore, thus making the learning process more fruitful.

5. Conclusion

In this paper, we showed a multitude of studies on the subject of Virtual Reality. This is a new technology which has to be tested in order to find the potential of use in different areas of our lives, be it enjoyment, education, training, etc. As there are some flaws in this technology, still, most of the studies on Virtual Reality emphasize its substantial benefits. Previous research is very helpful as it displays what has been done in this field as well as what new could be done. Furthermore, it answers some questions in regards if Virtual Reality could be used in specific scenarios and what outcomes to await.

This knowledge is not final, as there are more studies to come, some will be controversial as well, but it is already proved, that there is great significance in Virtual Reality applications and that Virtual Reality technology will take big part of our lives in the near future.

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