

A meta-analysis of the most influential factors of the virtual reality in education for the health and efficiency of students' activity

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
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Abstract. Learning focused on assimilation of facts, availability of information, free access to knowledge bases and convenient navigation in local and global networks is not a sufficient condition for the formation of an educated personality, active cognitive activity of the student. In the article, the authors the analysis of virtual reality factors influencing the effectiveness of educational activities and the preservation of the health of students. It is noted that learning in a synthetic environment causes the need to solve new, specific tasks, in particular, the teacher mastering the new role of a facilitator and understanding psychological and psychophysiological problems for health and the effectiveness of learning in a synthetic learning environment, the specificity of cyber-diseases. VR factors have been identified contributing to physiological differences in users: system factors, application and user interaction factors, individual and various factors of perception. Based on the results of research in the field of ergonomics, recommendations have been made, the consideration of which will contribute to reducing the risk of cyber-diseases.

Keywords: cyber disease, cognitive activity, virtual reality, immersive technologies, synthetic learning environment


1. Introduction

Digitalization of all aspects of our life is our reality and it can be considered only in relation to the best ways of implementation. As the Administrator of the United Nations Development Programme Achim Steiner says, “Our future is digital. If you’re not part of it, you’re out of it” [20]. It has especially acute form because of the current “polycrisis” evoked by the recent year, as it was defined at the World Economic Forum in Davos in January, 2023 [19]. As Joshi [13] highlighted, “In the past year, geopolitical risk roared back to the centre of world affairs, upending supply chains and disrupting major industries ranging from energy to food commodities. New technologies are also evolving quickly, and with these come new vulnerabilities, which attackers – some of whom have strong geopolitical motives – are often swift to exploit”. It concerns not only production market and workforce, but education and training because of needs in lifelong learning.

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The desire for openness of educational systems and the availability of powerful knowledge bases [5] today have not removed the relevance of solving the following problems of education:

- Predominant orientation of teaching methods on providing facts. However, having access to and consuming large amounts of information is not learning, and being informed is not the same as being educated.
- Many people experience difficulties with the perception of information. Too much information in a short time interval can easily overwhelm students. As a result, they become bored, alienated, and usually do not know why they are studying a certain topic, especially since the choice of information and the pace of its presentation are aimed at the “average” student.

And this trend persists despite the continued development and improvement of information and communication and network technologies, which expand the possibilities of digitalization of education. And this trend persists despite the continued development and improvement of information and communication and network technologies, which expand the possibilities of digitalization of education. New trends, directions, expectations, and risks on this way are considered at the international level. A meta-analysis of education transformation can be made based on publications after world-recognized companies and centers (f.e., Brookings Institution [9, 31]). Such predictions were made after analysis trends in Education & Development and Learning and Employment Records that combine innovations in learning, development and practices as requirements of the world market. According to authors, main expectations are as follows: Distributed Ledger Technologies, Artificial Intelligence, Cloud-Based Technologies as well as Virtual Reality and Augmented Reality. It is necessary to take into account discussions related to the role of metaverse for educations. Many experts strongly believe that f.e., “the metaverse is the future of online education” [7]. At the same time, the metaverse is associated with extended reality. All above mentioned innovations in education area deal with a human and technique interaction, i.e., automation of a human work. The fundamental analysis and prediction in this field have been made by Hancock et al. [11].

Immersive technologies are used widely in many areas of humans life and work, and education involves these tools actively for different tasks [24].

The history of the use of computer-oriented virtual learning environment as examples of both negative and positive impact on students: on their learning results, cognitive load and metacognitive judgments, the cognitive sphere of the individual as a whole [30].

Many years of general experience in the use of virtual reality (VR) can be used to increase interest in learning, motivation to study students with aim to identify and to build a competence recognition [14] and therefore activity in mastering knowledge.

VR education can change the way educational content is delivered; it works on the premise of creating a virtual world – real or imagined – and allows users not only to see it, but also to interact with it. Immersion in what is the subject of study motivates to a more complete awareness and understanding [15]. Therefore, less cognitive load is required to process educational information.

Purpose. The article is to carry out a meta-analysis of the most influential factors of virtual reality for the effectiveness of educational activities and for the preservation of the health of students.

2. Results and discussion

Results are discussed in two directions: properties and categories of VR use in education, factors contributing to the development of cybersickness.

2.1. Properties and categories of VR use in education

As it was stated, the synthetic educational environment enlarged education process into new dimension covering different types and forms of immersive tools and means, integration level of people and digital technologies, as well as cognitive and physical forms of human behavior and activity [2, 27]. VR at all levels of virtuality can be associated with the synthetic environment and can affect a human health and performance [10].

Among the properties that make virtual reality so powerful in education, we can highlight several the most important ones:

- a better sense of place,
- scaling of educational experience,
- training in practice,
- emotional reaction,
- development of creativity,
- visual learning / visualization of learning objects / visualization of learning,
- readiness of users to accept/use/perceive new technologies.

Where can we apply virtual reality in education, is quite clear: almost everywhere Burov, Bykov and Lytvynova [3]. VR creates an endless array of possibilities for people to experience. To date, several categories (types) of educational experiences using VR can be distinguished:

- virtual tours,
- high-tech training,
- internship,
- group training,
- distance learning,
- pedagogical design.

VR learning success stories tend to have the following common features:

- immersiveness of cognitive activity,
- ease of use,
- content of learning,
- adaptability to VR,
- impact/outcome measurability.



Figure 1: New tasks of learning in a synthetic environment.

Learning in a synthetic environment makes it necessary to solve new, specific tasks (figure 1). Some explanations can be made in such a way:

Making VR accessible. VR has a high price tag, which is a significant barrier for many users. If we analyze the success of Google Expeditions, it becomes clear that Google was able to reach so many students because the hardware was really affordable [15]. To make VR education accessible to the majority of users, it is important to focus on creating VR experiences for devices that users already have, such as smartphones, and repurpose them as powerful learning tools. A phone in our pocket and a not expensive headset like the Google Cardboard or Samsung Gear VR are all it takes for students to have a good VR experience.

Teacher's new role. The transition from analog to digital learning practices changes the teacher's role from content delivery to content facilitation. Information blocks (parts of content) should be more structured, accessible for perception (easier, clearer). The teacher carefully directs the learning process and helps the student (group of students) to achieve a clearly defined educational goal. The teacher actively, but not directly, creates a field for the transformation of thoughts and improvement of skills. The main task is to direct the educational process through the organization of a synthetic learning environment, to support participants in the realization of their educational goals. Instructors will focus on creating conditions for research/search rather than providing ready-made knowledge.

Understanding of the immersive effect. We are all in the early stages of learning VR and it will change [1]. However, technology will continue to push the boundaries of how immersive VR can be. In the coming years, we can expect to see advances in eye and body tracking.

Understanding of psycho [physio] logical problems in a synthetic learning environment, the specificity of cyber-diseases. Already in early virtual reality systems, abnormal visual-vestibular integration and vergence accommodation (Vergence-Accommodation Conflict) were detected, which caused cybersickness [21], which resembles exercise sickness reported by military pilots

[18]. Improved data processing, head tracking and improved graphics were expected to overcome or even help avoid cybersickness, but the expectation was wrong [6]. This issue needs to be addressed as VR and Augmented Reality (AR) are being deployed for stressful task training, PTSD (Post-Traumatic Stress Disorder) exposure therapy, remote assistance/monitoring, and operational situation awareness [22].

Until now, despite the long experience of using VR in various fields, the causes of the corresponding cyber-diseases have practically only begun to be studied. So, for example, the experience of virtual reality is often associated with a negative effect, cybersickness, which leads to nausea, disorientation and visual discomfort. In order to quantitatively analyze the degree of cybersickness depending on different attributes of VR content (i.e., camera movement, field of view, trajectory length, frame reference, and controllability), Oh and Son [23] generated benchmark cybersickness content with 52 VR scenes that present different content and have different attributes. The cybersickness assessment protocol was designed to collect the subjective opinions of 154 participants as reliably as possible, combined with objective data such as virtual reality scenes and biological signals. It has been shown that the severity of cybersickness is strongly correlated with six biological features that reflect the neurophysiological activity of the brain: the relative spectral power density of Fp1 delta, Fp1 beta, Fp2 delta, Fp2 gamma, T4 delta and T4 beta waves with a coefficient of determination greater than 0.9. In addition, the experimental results showed that individual characteristics (age and susceptibility) are also quantitatively related to the level of cybersickness. Notably, the created dataset contains a number of labels (i.e., subjective indicators of cybersickness) that correspond to each VR scene, which allowed the authors to create cybersickness prediction models and obtain reliable predictive indicators.

2.2. Factors contributing to the development of cybersickness

Cybersickness is a concept that does not qualify as a nosological form, although it is described in the scientific literature quite widely (the number of uses of this term on the Internet is about 200,000). We agree with authors of the international expert group, who defined cybersickness as “discomfort that users experience during or after a session in a synthetic environment” [10, p. 19]. And we believe that it should be extended on not only VR, but other forms of synthetic environment, because statistics of children’s health disorders are reported worldwide every year regards computer and other gadgets games, surfing etc.

The detailed analysis reason and factors contributed to the appearance of cybersickness in VR has been made by the international research group. In relation to the use of VR, more than 50 factors have been identified over time that can contribute to physiological differences in users [17]. We agree with such an analysis, but propose to specify its results.

They are divided into three categories of factors:

1. System factors – introduced by the hardware and operating system.
2. Application and user interaction factors – caused by the design of the software (such as a game), the user experience, and the way the user interacts with the application.
3. Individual and various factors of perception, characteristic of the user and caused by the level of his health and well-being.

Accordingly, the approaches of Pinchuk et al. [25] applied to VR design taking into account the recommendations and research results in the field of ergonomics are important.

The most common ones that can be considered to reduce or prevent the occurrence of cyber-disease are the following (figure 2):

Viewpoint/view control	<ul style="list-style-type: none"> • Users should be able to actively control the view point • Camera movement should be as predictable as possible • Any non-user-initiated movements should be reduced or eliminated
Presence of visual acceleration	<ul style="list-style-type: none"> • Accelerations should be avoided or limited • It is desirable to maintain a constant speed • Developers should think of the different types of allowed camera-initiated movements
Use of visual leading indicators	<ul style="list-style-type: none"> • Display visual indicators or movement trajectories
Signals/cues that provide stability	<ul style="list-style-type: none"> • Foreground tooltips that stay locked in the viewport when the user moves • Background cues: tied to the user's inertial frame of reference
Dynamics in the field of view display	<ul style="list-style-type: none"> • The field of view should be dynamically reduced based on the linear or angular velocity of the virtual environment • Implementation of dynamic blurring of unimportant/invisible areas

Figure 2: Recommendations and research results in the field of ergonomics.

Explanation of these recommendations can be as follows:

1. *Viewpoint/view control*: a) users should be able to actively control the view point and the resulting movement should be predictable for the user; b) in a similar way, all movements of the point of view of the camera should be as predictable as possible; c) any non-user-initiated movements (i.e. any movements not related to the user's own spatial navigation) should be reduced or eliminated, because artificial movement of the user increases the risk of nausea, especially for sensitive people [32].
2. *Presence of visual acceleration*: a) linear or angular accelerations without appropriate vestibular stimulation should be avoided or limited; b) it is desirable to maintain a constant speed, since it does not affect the vestibular system of most users; c) developers should think of the different types of allowed camera-initiated movements in their experience as a spectrum of tolerance, where the following listed movements are more likely to cause symptoms: user movement (natural) > linear visual movement > visual acceleration > visual rotation > visual acceleration + rotation.
3. *Use of visual leading indicators*: display visual indicators or movement trajectories (eg, arrows indicating the future direction of movement) so that users can predict future visual movements.

4. *Signals/cues that provide stability*, the presence of a frame of reference (Rest-Frame Cues): displaying visual cues that remain stable during the user's movement, providing them with fixed points that can help evaluate the movement. There are two general types of tooltips that can be displayed: a) foreground tooltips that stay locked in the viewport when the user moves (eg cockpit, car panel, helmet, etc.); b) background cues: tied to the user's inertial frame of reference (e.g. clouds, mountains, horizon, etc.).
5. *Dynamics in the field of view display*: a) the field of view should be dynamically reduced based on the linear or angular velocity of the virtual environment in order to reduce the number of scene movements perceived by the user's peripheral vision; b) implementation of dynamic blurring of unimportant/invisible areas.

The authors offer a more systematic analysis of factors that affect the effectiveness and prevention of cyber-disease in a synthetic learning environment using AR/VR in a previous work [4] but recommend also taking into account the individual learning style [8], which can change in a synthetic environment.

Considering that the transformation of education is accompanied not only by the expanded use of synthetic learning environments, but also by an increasing gaming moment in the learning process [26], an important aspect is to understand the difference in how the use of VR affects the possibility of cybersickness in the player and the observer of the game (i.e., passive participant). To better understand this problem, a team of scientists from Konkuk University interviewed 20 people and observed their experiences by studying eye movements. Using a VR game called the Collecting Ring Game (which has already been proven to be harmful), the researchers divided participants into a playing group and a watching group [12]. While the playing group experienced the actual game, the observer group watched a recording of the same game. Eye movements were recorded using a special monitor with a mirror. The researchers found that observers experienced significantly more negative symptoms than players. This may be due to the fact that players feel more in control of the situation or are better immersed in the virtual environment. The observers had shorter eye movements with longer periods of fixation in one place. This could have resulted in more brain damage than the players. The study showed that eye movement can be a possible diagnosis of the occurrence of a cyber-disease, and in addition, it can be concluded that the nature of such activity has many common features and signs of the operator's activity.

We strongly believe that considering all ergonomics features of the immersive environment [28], especially network-centered [16] and generally appeared in process of ICTs' evolution [3], can improve safety and efficiency of learning process. But learning and self-learning in the Metaverse needs new knowledge concerned a human and immersive environment integration [29].

When using the term "Metaverse", we emphasize that the environment of human activity (work, study, everyday life) will be significantly changed by virtual and 3D technologies already in the near future. This new social space needs new research. The metaverse as a convergence of a virtually augmented physical reality and a physically persistent virtual space can be characterized by mutually reinforcing ways of virtualization and 3D modeling, and therefore can potentially have both advantages and disadvantages, as well as unintended consequences. Both augmented reality and mirror worlds offer context-aware versions of Google or Wikipedia,

quickly accessible and understandable. In contrast, lifelogging, and virtual worlds, being more personal, offer tools for a more detailed understanding of one's own life and relationships. Another question is, does all this mean an improvement in understanding, especially when these technologies that are not yet sufficiently advanced? Therefore, it is imperative to pay attention to the special benefits and challenges associated with future education.

3. Conclusions and future research

The digital transformation of the education system, the wider use of distance learning, as well as the Internet and the metaverse as an extension of the latter, are accompanied by an increase in threats for participants of the educational process both performance efficiency and health.

New tasks of learning in a synthetic environment can be highlighted: the new role of the teacher, changing (impermanent) understanding of the immersive effect, making VR accessible, understanding psychological and psychophysiological problems for health, and learning effectiveness.

VR factors have been identified contributing to physiological differences in users: system factors, application and user interaction factors, individual and various factors of perception.

The general recommendations related to the VR design and application for education goals are to pay attention to: viewpoint/view control, presence of visual acceleration, use of visual leading indicators, signals/cues that provide stability, dynamics in the field of view display.

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