Analysis and Modeling of the Negative Impact of Virtual Reality

N Vehteva¹, A Nazarova¹, E Surkova¹
¹Tambov State Technical University, 392000 Tambov, Russian Federation

E-mail: nazarova.al.ol@yandex.ru

Abstract. During the use of virtual training complexes for the training of specialists in the engineering, chemical, mining industries, in the course of numerous studies, the negative impact of virtual reality on the physical state of a person is noted. These include various types of motion sickness, dizziness, nausea, disorientation in space. Therefore, an actual task is researching of causes and the degree of influence of negative factors using virtual reality technologies. To track negative effects, an algorithm for analyzing user’s state has been developed, which allows collect data of person’s state during the interacting with virtual reality. The algorithm allows fixing quantitative and qualitative metrics. Calculation of metrics is formalized in a mathematical model of process of the virtual reality influence on a person. Algorithm and model are tested on example of an exercise on moving simple virtual objects, data is obtained on a focus group of young specialists. Dynamics of changing quantitative and qualitative metrics is evaluated; it received an idea of degree of influence of negative effects on studying process.

1. Introduction

One of the modern means of training personnel for work is the use of virtual or augmented reality technologies [1]. The previously used traditional approaches are not always effective in organizing training for people to work in normal and emergency situations [2-4]. They cannot simulate the entire spectrum of events, physical and chemical processes due to the danger to the health and life of the trainees [5, 6].

According to current trends in education [7-10], industrial safety [1], visualization [11], marketing [12] and many other industries, it can be assumed using immersive technologies will increase over time. It is facilitated by improving quality and availability of existing hardware and software for virtual reality (VR) devices [2, 8]. However, the problem of VR impact on human’s health remains open. However, to study this issue, it is necessary to collect data on the interaction with VR and formalize the learning processes [13, 14].

It has been noted some users experience discomfort using VR headsets. List of possible symptoms includes nausea, dizziness, headache, disorientation, oculomotor disturbances, cold sweat, etc [15-18]. Observed negative effects resemble seasickness, however, their occurrence as a result of interaction with full immersion devices is called “cybersickness” [19-20]. Most common hypothesis for this disorder is called the sensory conflict theory. Less popular are the theory of poisons and postural instability [16-17, 20]. However, none of them explains the reason why people have different manifestations of cybersickness.
For formalizing the process of the negative impact of virtual reality, it is necessary to implement an algorithm for analyzing data on user’s state, including the collection of the necessary metrics [14]. Next, it is required to form a mathematical model of process of virtual reality impact on student. Based on obtained theoretical results, necessary software components for assessing the impact of virtual reality technologies on the specialists training process will be formed.

2. **Algorithm for analyzing user’s state data in virtual reality**

Consider algorithm collecting data on user’s state in virtual reality, allowing us to generate a list of quantitative metrics: accuracy, exercise time, number of errors. Also, data collection allows obtaining a number of quality metrics: assessment of negative factors from using of virtual reality [21].

Algorithm includes four main stages (figure 1):

![Figure 1. Algorithm for analyzing data about the state of the user in virtual reality.](image-url)
1. Entering personal subject’s data and authorization in the simulator (collecting personal data).
2. Passing exercises in virtual reality (collecting quantitative metrics).
3. Taking a survey (collecting quality metrics).
4. Analysis of the collected data, visualization.

At the first stage, the student enters his personal data. Then, student selects exercise and virtual scene settings. The exercise "Moving Simple Objects" was used as a test scene (figure 2). It allows developing basic skills for moving in virtual space and positioning the simple objects [22].

The scene includes: room with user avatar; test bench with an objects set of different sizes. Next to objects - color-coded target areas in center of which is necessary to place it.

During the exercise, the software reads three main metrics:
1. accuracy (average distance between the center of the object and the center of the target area);
2. exercise time;
3. number of errors (object didn’t hit the target area).

Further it carried out the survey, which provides quality metrics to assess the negative impact of virtual reality:
1. Feeling nauseous.
2. Feeling of motion sickness.
3. Feeling dizzy.
4. Feeling disorientated.

The result of the completed survey is recorded in the database with the user ID.

After completing the exercise, it is necessary to process the received information to identify patterns of virtual reality influence on state of people of different ages, gender and experience of interacting with digital devices.

![Figure 2. Virtual scene "Moving simple objects".](image)

3. Mathematical model of process of virtual reality impact on a person
Developed algorithm allows forming a database containing information about the personal data of trainees, quantitative and qualitative metrics. Thus, the following information object is defined for each user:
where
- set of user’s parameters (gender, age, weight, field of activity, and others);
- set of quantitative metrics;
- set of quality metrics;

To determine quantitative metrics, we will use the following formulas.

Accuracy of interaction with virtual reality objects:

\[ M_A = \frac{\sum_{i=1}^{Q}|x_i - x_R|}{Q}, \quad (2) \]

Exercise time:

\[ M_T = T_f - T_0, \quad (3) \]

Number of mistakes:

\[ M_E = |X_L|. X_L = \{x_i \mid |x_i - x_R| > \Delta x\}, \quad (4) \]

where
- \( Q \) - amount of exercise repetitions;
- \( x_i \) - virtual object’s coordinates;
- \( x_R \) - coordinates of target area (receiver of virtual objects);
- \( T_f \) - end time of the exercise;
- \( T_0 \) - start time of the exercise;
- \( X_L \) - set of virtual objects, the coordinates of which are outside the work area of the exercise and their placement is considered erroneous.

For each qualitative metric, we will use the following formula:

\[ N_k = \frac{\sum_{i=1}^{U}n_{ik}}{|U|}, \quad (5) \]

where
- \( |U| \) - number of trainees in the sample;
- \( n_{ik} \) - i-th student’s answer on k-th question during the exercise;

Collected data as an information object can be processed by various methods to identify patterns of the virtual reality influence:
- statistical analysis of the collected data to find patterns between the initial indicators of users, used by the components of training complexes and the final training quality indicators [18];
- construction of approximating functions that allow predicting dynamics of user learning according to given initial indicators;
- development and training of a multilayer neural network to identify patterns between the initial user’s characteristics, used components of training complexes and the final training quality indicators, as well as to predict the dynamics of the learning process [19];

Thus, we obtain the following mapping of \( F_{VR} \):

\[ F_{VR} : (P, VR) \rightarrow (N, M), \quad (6) \]
where $VR$ - set of virtual scene parameters (size, number of objects, the nature of interaction with them, types of exercises, etc.) Determine the calculated mapping formula of $F_{VR}$ perhaps one of the methods discussed above.

4. Testing of the developed algorithmic and mathematical support

Based on obtained theoretical results, development of necessary software integrated into virtual space for collecting quantitative and qualitative metrics was carried out. Consider obtained metric values on example of one of test sample students (age group under 25).

Figure 3 shows the change in quantitative characteristics for 5 attempts. It can be noted with each repetition user improves metrics values: accuracy increases, and number of errors and test time decreases.

![Figure 3. Dynamics of quantitative metrics of the learner.](image)

Figure 4 shows the dynamics of changes in qualitative metrics collected after each exercise. It can be noted after the second repetition the student was already able to adapt to virtual reality. Negative effect on him decreased significantly by the end of the experiment.

The student also noted after several repetitions of the exercise, he was able to sufficiently master the tools for interacting with virtual reality and effectively use them to complete tasks.

A survey of focus group participants also revealed the following aspects of the impact of virtual reality:
- the need for additional training before working with controllers to acquire basic skills;
- a small number of participants constantly experienced negative effects;
- the severity of negative effects depends on the amount of movement in the virtual reality helmet;
- getting used to the angle of view in the helmet;
- interaction with objects in virtual reality is more natural than using tools such as a mouse or keyboard.
5. Conclusion
The paper contains algorithmic and mathematical support for the process of the negative impact of virtual reality technologies on a person in the process of learning on training complexes. To investigate patterns of influence of these technologies, we propose an algorithm for collecting, analyzing and processing data about user’s state in virtual reality. A set of metrics formalized as software is proposed to assess to user’s state.

Within the framework of the considered algorithmic and mathematical support, the main quantitative and qualitative metrics characterizing the effect of virtual reality on a person are highlighted. Quantitative metrics include accuracy, exercise time, number of errors. Qualitative metrics include an assessment of a person's condition according to 4 signs: nausea, motion sickness, dizziness, disorientation.

The developed algorithmic and mathematical software was used to collect data; the results of one of student are presented. However, it is necessary to conduct large-scale test to form correctly defined relationship between a user’s parameters and the influence of virtual reality. A large amount of data will make it possible, on the basis of statistical, mathematical or intellectual methods, to determine the degree and nature of the influence of certain properties of virtual reality on a person.

6. References
[1] Gavish N, Gutiérrez T, Webel S, Rodriguez J, Peveri M and Bockholt U 2013 Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks Interactive Learning Environments 23(6) 778–98
[2] Feng Z, González V A, Amor R, Lovreglio R and Cabrera-Guerrero G 2018 Immersive virtual reality serious games for evacuation training and research: A systematic literature review Computers & Education 127 252–66
[3] Patle D S, Ahmad Z and Rangaiah G P 2014 Operator training simulators in the chemical industry: review, issues, and future directions Reviews in Chemical Engineering 30(2) 199-216
[4] Lang Y, Wei L, Xu F, Zhao Y and Yu L-F 2018 Synthesizing Personalized Training Programs for Improving Driving Habits via Virtual Reality 2018 IEEE Conference on Virtual Reality and 3D User Interfaces (VR) (IEEE) pp 297-304
Acknowledgments
The reported study was funded by RFBR according to the research project 19-013-00567. The work performed by the Laboratory of medical VR simulation systems for training, diagnosis and rehabilitation using the computing equipment of the Center for Collective Use "Digital Engineering".