The effects of Virtual Reality technology application in the aircraft pilot training process

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Abstract. In this study, we focus on some problems related to virtual reality technology usage in supporting the educational process. The main goal is to obtain the optimal duration of exposure to virtual reality without the appearance of physiological problems for the user affected the achievement of teaching outcomes. Most of the characteristics of virtual reality software at the same time point out some issues in the areas of technological innovations, especially in the health context. The presented example of the VR environment's training application shows the effectiveness of VR methods and their possibilities in training aircraft pilots. Teaching involving VR allowed to achieve, on average, as much as 90% correct answers, which in comparison with traditional methods resulted in an increase of 21 to 32.7% of correct answers in comparison with training using VR. The research confirmed that a critical challenge in the context of the broader use of VR in education is to appropriately adapt the learning materials and content to the technical requirements. Then, in certain areas, the use of VR is beneficial.

1. Introduction
The first paragraph after As a result of the popularization of low-cost mobile devices, modern technologies, so far practically present only in research and development laboratories, have become available to every user. The growing popularity of mobile devices with more and more affordable wireless access to the Internet contributes to the mobile market's dynamic growth [1].

Virtual reality (VR) and augmented reality (AR) technologies are currently one of the fastest-growing information technology areas. VR is a technique that is based on mapping a fragment of the real world in a computer environment. The solution's essence is the implementation of various scenarios, narratives, or simulations, which in the main thing have a software character [2].

Some researchers, as also one of the world's leading inventors Ray Kurzweil claims that by the 2030s virtual reality will replace the real biological world [2]:

"... By the end of this decade, we will have full-immersion virtual auditory environments, populated by realistic looking virtual humans. These technologies are evolving today at an accelerating pace, as reflected in the book Virtual Humans. By the 2030s, virtual reality will be realistic and compelling, and we will spend most of our time in virtual environments. By the 2040s, even people of biological origin are likely to have the vast majority of their thinking processes taking place in nonbiological substrates. We will all become virtual humans."

In VR technology, interaction is one of its most essential components. There are three ways to achieve interaction: first, physical interaction is when reality can actually move to the virtual world through their devices; second, interaction through an agent, which means that users communicate with
computers and the computer helps them; and third, virtual interactions where the user's "devices" are inside the virtual world and users can feel contact directly from the virtual environment [3]. The article aimed to examine, diagnose whether there is any negative impact on the health condition of a person using VR/AR devices and its applications diagnose whether there is any evidence to conclude that the use of VR and immersive learning techniques create an advantage in the level of knowledge acquisition over traditional teaching methods.

2. Concepts and challenges on adoption VR/AR technology in the teaching process

There is an increasing global demand for using AR/VR products, and it is expected to continue rising. This turns into more demand for skilled workers and the need for new skills. In the case of many industries related to prototyping and production testing, it becomes essential to reproduce the product faithfully and attractively in the right environment and atmosphere. Such possibilities are offered by VR (Virtual Reality) and AR (Augmented Reality) technology. However, it should be assessed whether the excessive use of technical innovations does not have a negative impact on the health and comfort of personal work [4][5].

Virtual Reality (VR) is a reflection of the artificial reality created with the use of IT technology, based on multimedia creation of computer vision of objects, space, and events. It can represent both elements of the real world (computer simulations) and entirely fictitious. When using VR devices, the user usually wears a special helmet on his head with a built-in display or glasses that are powered by a computer, game console, or smartphone. With specialized software and sensors, the virtual experience becomes a reality. Virtual transmission is usually amplified by 3D surround sound [6].

Augmented Reality (AR) is when the real reality is enriched with virtual images or data that coexist in the real world. Ronald Azuma defines AR as a system that combines the real world and virtual reality, interactive in real-time, enabling freedom of movement in three dimensions. Augmented reality does not create a new, entirely virtual three-dimensional world but "complements" the real world with new images or information. It can be a supplement in the form of pure information (navigation information, street names) or an extension based on complex photorealistic objects that blend into the real world and form a whole with it. The augmented reality is not the same as the virtual reality that creates a new world, generated by the computer using 3D technology. AR does not create "virtual worlds" but recognizes real-world objects and then imposes virtual information on them. Nowadays, AR applications place great emphasis on making virtual "extensions" indistinguishable from reality [7].

Mixed Reality (MR) is a mixed or hybrid reality, referring to a system that combines real and virtual objects with the information presented using augmented reality. MR tries to combine the best features of VR and AR [8][9].

Forecasts from various research centers clearly indicate that augmented and virtual reality will constitute a new turning point for developing multimedia technologies. Analyzing different prognosis one can see that the direction and value of the market will undoubtedly increase. According to CCS Insight, the number of sold VR and AR devices will increase from 2.5 million devices (2.2 million VR and 0.3 million AR) in 2015 to 24 million devices in 2018 (20 million VR and 4 million AR). A very high percentage of VR devices sold, as much as 90% in 2018, will be devices based on smartphones. The value of the AR market is expected to increase from $300 million at the end of 2015 to $3.6 billion at the end of 2018, which implies a value of the VR market of about $18 billion [10].

3. Health aspects of Virtual Reality technology perceptions

In [11], the authors stipulate that virtual reality can be defined as a computer-generated scenario in which the user can interact with the scene. This can be ensured by the fact that the VR system consists of external tools (senses), internal tools (gloves, joysticks, etc.), a graphics rendering system that creates a virtual environment, and software and database that work together to create a virtual reality system and real reality.

In VR technology, besides the undeniable advantages, we can see that some drawbacks hinder its use in many applications, e.g., in educational institutions, industry, etc. The problems that are often
presented in the literature are primarily a health problem - physical and physiological problems that affect the individual after exposure to virtual reality. There are physiological problems such as foggy vision, changes in the heart and blood vessels, change in motor skills, change in cognitive control, eye fatigue, abdominal pain, depression, hallucinations, visual impairment, digestive disorders, disorientation, instability, respiratory disorder, stress, and finally addiction [12][13].

Some research concerns the causes of pathological symptoms related to virtual reality exposure to certain factors such as head and body movement, data rate updates, exposure time, and repetition [14]. There are other symptoms with long term use of VR, such as marine disease and disorientation. This result is confirmed by a study presented in [16]. The authors explained that time is a significant factor in emerging movement symptoms in the virtual scene. These symptoms can continue for a short time, especially in the case of entanglement and visual stress. Repeated exposure to virtual reality is another factor that caused some adaptation. In [17], authors addressed exposure over a long period of time, leading to increased sensory conflicts and physiological problems, and repeated sessions lead to adaptation to sensory conflict.

Simulator sickness or cybersickness is a sideproduct of high-quality visual simulators and virtual interfaces. It resembles the more famous locomotive disease, including, but not limited to, blistering, dizziness, headache, and nausea. While many of the symptoms of the simulatory disease and motion-related diseases are similar, the severity and incidence of simulator sickness symptoms are usually lower than those associated with motion discomfort. Still, in many cases, they are significant [15].

Simulatory disease and vision-induced locomotive disease are considered to be the result of an imbalance between sensory experiences and expectations. It can be assumed that more visually complex simulations may contribute to a noticeable discomfort. It is also predicted that the patient's locomotor control in a multi-dimensional environment, together with the use of sensory feedback, will result in a reduction in the results of the disease simulation [17].

Simulation disease is an essential factor in assessing the profitability of an immersed virtual environment [18].

4. Example of a VR training session in a selected University teaching module

The purpose of the sample training application in the VR environment was to familiarize students with the Socata TB-9 "Tampico" training aircraft's essential elements. (Figure 1), seven units of which are owned by the Aviation Education Centre of the Rzeszów University of Technology. In addition to mapping the interior, based on previously taken photographs, an exercise was programmed as the fully immersive VR lesson in order to make it easier to remember the pre-start procedure of checking the cockpit.

Figure 1. Socata TB-9 "Tampico" airplane located in the Aviation Training Centre of the Rzeszów University of Technology.

The availability of VR equipment limits the number of participants. It should be remembered that the trainer should supervise the training process, sometimes moderate and change the course scenario, so the number of students cannot be too high. Students can practice simple procedures independently, but in further stages of the training, feedback from the trainer, assessment of student behavior, etc. is
essential, which requires continuous observation by the trainer. Due to health aspects, the time spent in VR glasses cannot be too long at once.

4.1. Details of the implemented training procedure
The procedure selected for the presentation is called "Preflight - cockpit". It consists of six steps, as shown in Table 1. The third column describes each of them. Modeling individual elements of the cockpit was done using Blender 2.80 tool distributed under GPL license. The virtual cockpit's comparison with the real aircraft cockpit is presented in Figure 2 and Figure 3.

Each time the button is pressed, it also triggers the playback of the sound that imitates this action, requiring the addition of an "Audio Source" component to operate (Figure 4). The list of tasks to be performed by the user has been decided to place it as an element of the cockpit just in front of his face so that it is visible. Inside it, there are previously prepared graphics with a list of tasks and a symbol indicating that the activity has been completed (Figure 5).

![Figure 2. Cockpit model with textures based on real model (fig. 3)](image1)

![Figure 3. Photograph of the real cockpit.](image2)

![Figure 4. “Main Switch” on (left) and the indicators it activates (right).](image3)

| Cocktail element | Cocktail element status | Activity description |
|------------------|-------------------------|----------------------|
| Ignitions switch | OFF                     | Checking that the ignition switch is in the off position; |
| Controls lock    | REMOVED / CONTROLS FREE | Checking if the rudder lock has been removed / can the rudder be moved; |
| Master switch    | ON                      | Switching on the main switch; |
| Voltmeter        | CHECKED                 | Checking the voltmeter display (green field display); |
| Fuel quantity    | CHECKED                 | Checking the fuel level in both tanks; |
| Trimmer          | CHECKED / SET           | Checking the calibration of the rudder; |
Figure 5. The object of the "Canvas" type containing a list of tasks.

4.2. The training procedure of the exercise

After putting on the VR goggles, the person who is practicing sees the virtual cockpit inside. The purpose of the training, in this case, is the pre-start procedure. The actions to be performed are displayed in the form of a board located above the instruments in front of the player. Virtual gloves are used to interact with the environment and are controlled by HTC Vive controllers. Pressing a specific button of the controller puts your fingers in a corresponding gesture. Due to the small size of the cockpit elements, it is advisable to make a virtual glove gesture in which only the index finger is straightened (Figure 6). An attempt to interact with an open hand can result in contact with many elements simultaneously.

Figure 6. Glove gesture with index finger straightened out. Figure 7. Rudder object during the animation.

In the course of the procedure, some activities actually consist of a visual assessment of the element. Due to the need for the application logic to recognize whether a given action has been performed, the visual check should be additionally confirmed by touching the element. In the second task, where the possibility of manipulating the rudder has to be checked, touching the rudder starts the animation that moves it (Figure 7).

Activities 1, 2, 3, and 6 can be performed in any order. The fourth and fifth task requires to pass the first step no. 3 to pass correctly. This is related to the voltmeter and fuel level indicators' activation only after turning on the main switch. Turning off the main regulator not only cancels task no. 3, but also tasks no. 4 and 5. Despite the almost complete freedom to go through the procedure, the elements are marked with a pulsating backlight in the order that has been saved on the board. The light changes its diameter (Figure 8), which attracts the user's attention so that he finds the object he is looking for faster.
5. Application data analysis
Seventeen people tested the application described in section 4. Participants had not previously had the opportunity to sit in the cockpit of the simulated aircraft type. Each of them practiced the procedure once, wearing HTC Vive goggles for a session of a maximum of 5 minutes long.

Then the participants were asked to complete a survey consisting of 8 questions.

5.1. Data analysis
The first two questions in the survey concerned the demographics of the study group. Application users were people aged 21-23, among whom there was only one woman.

In the question about the level of difficulty of the controller movement and manipulation, the average result on a five-point scale was 2.26. Probably such a low value is the result of inadequate knowledge of the used set. Thus lack of practice in using controllers and the specifics of the created application in which interaction with small cockpit elements is severe. None of the participants indicated the highest rating in this question (Figure 9).

When asked if the prompts displayed were sufficient to successfully complete the exercise, sixteen people answered in the affirmative. Only one person chose "No" (Figure 10a).

Only 11 people answered that they would be able to reproduce the practiced procedure on a real airplane. Six people had a different opinion (Figure 10b).

The statistics for answering the question were the same: "Would you use a VR kit to learn with it?" However, the question of whether learning using virtual reality can be effective was answered by 15 out of 17 respondents. The last question was about any discomfort or symptoms associated with using VR goggles. Fourteen people did not experience any trouble. Three people indicated the occurrence of unwanted symptoms (Figure 10c).
Figure 10. Graph of answers to questions about (a) whether the prompts were displayed sufficient to successfully complete the exercise (b) question: “Do you think that you would be able to recreate rehearsed procedure in a real plane? (c) discomfort or unwanted symptoms associated with using VR goggles.

6. Conclusions
Based on the study results, it can be concluded that virtual reality is already recognizable among young people who are, by nature, the social group with the most incredible openness to new technologies. The most significant disadvantage is the high cost of the sets, which can be seen as the reasons for the still low popularity of VR sets among ordinary users, despite their reasonably good knowledge of the technology itself. This also confirms the question about the number of users willing to spend on their purchase - the vast majority of people gave a value several times lower than the current cost of the most popular sets.

Among people who had the opportunity to experience virtual reality, the vast majority used them for entertainment purposes. Only about 30% of them have learned the possibilities of virtual reality in the context of education or work. Statistics are much better for the possibility of ultimately transferring a given field of life to virtual reality. Entertainment still dominates here, which was indicated by 69% of respondents, but 57% marked education. The user's perception of the possibility of using virtual reality for teaching purposes also confirms 84% of opinions indicating the effectiveness of learning using it. On the other hand, only 40% of respondents said they had had contact with VR content not intended for entertainment purposes. Nearly 60% of respondents pointed to the possibility of full popularization of virtual reality sets in the future. These statistics show a great interest in technology and might be a predictor for its rapid development in the near future.

Almost half of the people did not experience discomfort or side effects associated with the use of VR kits. However, we do not know the time they used them. Among people who complained about negative feelings, the period after which it happened often did not exceed 30 minutes. Therefore, it is possible that if you use your goggles for a long time, a more significant percentage of people would report problems. One can also notice a high awareness of threats to the psyche of users among respondents. Health issues should, therefore, be a priority for both equipment manufacturers and content creators. The sense of reality in the virtual reality environment was highly rated by respondents. Interestingly, the mere isolation from the real world in respondents' opinions just as much affects the perceived effect of telepresence as the quality of stimuli provided.

Statistics on the type of ownership and used virtual reality kits indicate large market shares in the most recognizable companies' solutions. Goggles using a smartphone, despite a much lower price, are not very popular. It probably results from a much lower quality of stimuli they provide.
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