

IMMERSIVE TECHNOLOGIES FOR IMPROVING THE WELL-BEING AND QUALITY OF LIFE OF PEOPLE WITH DISABILITIES: CURRENT SOLUTIONS AND IMPLEMENTATION CHALLENGES

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Abstract. This article examines the current and potential applications of virtual reality technologies for people with various physical limitations resulting from injuries or illnesses. The Russian market for virtual tools in medicine is examined, and the challenges faced by medical centers in Russia when using immersive technologies for rehabilitation and therapeutic interventions are identified. The shortcomings of current technologies in improving the satisfaction and quality of life of end-users with disabilities are highlighted.

Keywords: virtual and augmented reality technologies, inclusive environment, rehabilitation, people with disabilities, satisfaction and quality of life.

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Introduction

Currently, virtual reality (VR) and augmented reality (AR) technologies are being applied in virtually all areas of life. Immersion (from the English word “immersive” — “presence, immersion”) is a mode of perception that creates the effect of being immersed in an artificially created environment [3]. In recent years, developers and users have aimed to create fully immersive virtual reality technologies, where the distinction between the illusory and real worlds is blurred. However, creating such a system involves a number of challenges, including the accessibility of these technologies to a wide range of users [2]. People with disabilities constitute a distinct group among them. The application of immersive technologies for this group should not be limited solely to rehabilitation following surgeries, injuries, and serious illnesses.

The aim of this study is to analyze current solutions and challenges regarding the use of immersive technologies by people with disabilities to improve their satisfaction and quality of life.

Materials and Methods

To achieve this objective, we analyzed publications on the research topic contained in Russian and international sci-

entometric databases, including Scopus, Web of Science, and RINC, as well as online resources of VR equipment manufacturers, for the period from 2019 to 2025. In addition, we examined statistical data on the number of people with disabilities in the Russian Federation (hereinafter — RF) and their ability to lead an active lifestyle, the prevalence of virtual reality technologies in the RF and their application in medical centers within the RF, the availability of educational programs for training developers of VR and AR solutions, including in medicine, as well as virtual scenario simulations for training doctors and nurses.

Results

A review of the literature revealed a wide range of applications for virtual reality technologies in medicine: VR can be used to train students, improve staff skills, prepare patients for complex surgeries, and facilitate rehabilitation [4; 19]. VR can be and is successfully used to help people with physical or cognitive impairments regain lost functions or learn new skills. For example, VR helps stroke survivors regain limb mobility and helps people with cognitive impairments, such as autism, improve their social skills. VR can also be used in telerehabilitation so that people with disabilities can receive therapy remotely.

This, in turn, can be particularly useful in rural areas. In other words, the use of VR in medicine significantly expands the possibilities for both doctors and patients [13].

Unfortunately, even with the most modern and comprehensive approach to rehabilitation, VR is not a panacea and by no means always leads to the desired results. The success of rehabilitation efforts is strictly limited by a number of factors: the nature and severity of the underlying condition (for example, in cases of extensive damage to the central nervous system or progressive neurodegenerative diseases), the patient's age, the presence of comorbidities, and the timing of treatment initiation. In some cases, the destructive changes in the body prove to be irreversible, and rehabilitation aims only at adapting to a new quality of life, teaching self-care skills, and managing secondary complications, without addressing the primary impairment. Thus, despite all efforts, full or even partial functional recovery may prove unattainable, and the primary goal becomes maximizing the improvement of the patient's overall condition and social integration within the limits of available VR technologies.

However, practice shows that immersion in virtual reality — i.e., the complete blocking out of the real world through the display of a virtual reality environment — is currently not universally applicable or accessible to many people with disabilities [18]. The application of VR technologies could meet a much broader range of needs for people with disabilities. For instance, VR can help break down barriers to access information, education, and entertainment. This is particularly important for this group of individuals, who do not have the same ability as others to receive information from traditional media sources. For example, people with musculoskeletal disorders can use VR to visit a museum, and people with paralysis can participate in virtual sports competitions or other events. A person in a wheelchair can use VR to experience hiking through the mountains, or a person with visual impairments can use VR to explore a city or other space. This can provide an “escape” from the limitations of their physical abilities and allow them to experience what would otherwise be impossible.

However, challenges remain that hinder the most effective use of virtual reality technologies by people with disabilities. Thanks to growing interest from investors and developers in these challenges, some of them have already been addressed.

According to a study conducted by K. Gerling, P. Dickinson, et al., wheelchair users are highly attracted to VR games, although creating an immersive experience for people with disabilities requires careful planning [12]. For example, Beat Saber (destroying flying cubes with lightsabers to music), Job Simulator (performing humorous office tasks in the future), AudioShield (deflecting colored energy waves that correspond to the rhythm of the music), BoxVR (performing boxing exercises to music for training), and many other games across various genres are engaging and

highly immersive. Now, players with disabilities can play the best VR games using the WalkinVR Driver assistive software [1].

Some examples of inclusive content include games that can be played without sound, offering real-time subtitles and audio-to-text conversion for users with hearing impairments or deafness. Games and apps designed for users with mobility impairments can also offer one-handed navigation or customizable controls [13].

Currently, VR games for the blind have been developed and are in use, in which blind people—wearing a pair of VR goggles, headphones, and a controller in each hand—can explore their surroundings using echolocation and feel as though they are in another world [16]. Such technologies can also be used by sighted people to foster empathy and understanding among the working-age population, allowing them to experience what it is like to have a disability (Fig. 1).



Fig. 1. Screenshot from the VR game Blind*

In addition, voice recognition technology is increasingly being integrated into VR and AR interfaces, allowing users to navigate virtual environments and interact with content without using their hands. This technology is particularly useful for users with mobility issues or fine motor impairments [13].

Another challenge for people with disabilities is the lack of haptic feedback in VR systems. Blind or visually impaired individuals may have difficulty navigating virtual environments without the ability to feel surfaces and objects within them. To address this issue, haptic feedback devices have been significantly improved. These devices simulate the sense of touch, such as gloves that vibrate, creating the sensation of touching an object or interacting with the virtual world [13]. Modern exoskeletons are capable of adapting to movements, making walking, flying, and swimming in the virtual world particularly realistic [11]. Such tactile experiences add a new level of immersion and accessibility for users with visual impairments. For example, thanks to new virtual reality sensors, it is possible to distinguish 20 types of fabrics by touch. Modern VR headsets are capable of simulating kisses and splashes of mud on the face [20].

* Source: URL: <https://strategie.ru/forums/threads> (accessed September 15, 2025).

Today, new technologies complement visual, auditory, and tactile sensations with aromatic effects [20]. Aromatic effects (olfactory technologies) in virtual reality can become not merely a supplement for blind users, but a key channel of information and a powerful tool for creating reality, compensating for the absence of the visual modality. The integration of scent-based stimulation into the digital environment not only enriches the immersive experience but also paves the way for more inclusive solutions for people with sensory or cognitive impairments [17].

1. Deep and intuitive immersion in the environment:
 - sense of place. A sighted person understands that they are in a forest by looking at an image. Blind people lack this information and, consequently, must rely on compensatory sensory channels and alternative methods. Research shows that smell is a rich source of contextual information for spatial orientation [14]. A blind person can gain the same understanding instantly through scents: the smell of pine needles and damp earth, the scent of decaying leaves in autumn, the aroma of blooming linden trees. This creates context and atmosphere faster and more effectively than any audio description;
 - navigation and spatial orientation. Scents can serve as navigational markers [17]. For example, the smell of fresh baked goods can lead to a virtual bakery, the scent of sea salt and seaweed can indicate approaching the shore, and the smell of smoke can warn of a dangerous area.
2. Enhancing and enriching the narrative and plot:
 - on an educational tour of Ancient Egypt, the scent of incense and papyrus will create a much stronger sense of presence than sound alone;
 - In a quest or story, the appearance of the smell of ozone can signal the activation of a “time machine,” while the smell of old wood and dust can transport the hero to the attic of an old house, where a key part of the plot begins.
3. Improving the accessibility of games and simulations:
 - taaactical cues. In a game, scent can be an important gameplay element. For example, in an adventure game, a visually impaired player might search for a hidden object based on its unique scent (e.g., an oak chest smells of old wood and metal);
 - danger warnings. The smell of burning or smoke can serve as an indicator of an approaching threat (a fire, an enemy with a flamethrower), giving the player time to react.
4. Emotional impact and strengthening the connection with content:
 - Scents are directly linked to the brain’s limbic system, which is responsible for emotions and memory. A study published in *ACM Computing Surveys* explores the design of olfactory displays for virtual reality environments, noting how the integration of scents enhances immersion and emotional engagement. Early prototypes are wearable devices that synchronize microdoses of synthesized scents with visual cues, overcoming longstanding limitations of multisensory experiences [10]. The scent of freshly cut grass can evoke feelings of calm

and nostalgia, while the smell of gunpowder and dust can trigger anxiety and tension. This allows for the creation of much stronger and more memorable emotional experiences than when using sound alone.

5. Compensating for information and creating a more complete picture of the world:
 - in the real world, blind people actively use their sense of smell to gather information about people, objects, and places [6]. Scented VR brings this effective strategy into the virtual space. Smell allows us to “see” what cannot always be described in words or sound: the freshness of a meal just cooked, the distinct smell of a hospital, the unique atmosphere of a temple.

One of the biggest challenges for people with disabilities is that many VR systems require the use of a handheld controller for navigation and interaction with the virtual environment. This can be a problem for people with mobility impairments, such as cerebral palsy or multiple sclerosis, who have difficulty moving their hands. To solve this problem, researchers are developing new forms of input, such as eye tracking and brain-computer interfaces, which allow users to control VR systems using their eyes or thoughts. Neuralink is currently testing a device designed to help people with spinal cord injuries. This chip is a neural interface that is implanted in the brain. The device can function even if a person has no eyes at all, by connecting to the brain’s visual centers. This allows the device to transmit visual signals directly to the brain, bypassing the eyeball and the optic nerve. As a result, patients can receive visual images even if their visual system is not functioning [9]. However, as of today, the technology is potentially capable of helping only if blindness is caused by damage to the eyes or optic nerves, while the patient’s visual cortex remains fully intact.

The use of VR to treat mental disorders and depression in individuals who have suffered from serious illnesses — which, in turn, have led to disability or physical limitations — is becoming increasingly important [15]. For example, among stroke patients, post-stroke depression is the most common mental disorder, developing in approximately one in three patients. According to some data, the prevalence of post-stroke depression reaches 60%. On average, depression develops immediately after a stroke in 50% of patients, during the acute phase in 12%, and during the early and late recovery phases in 29% and 9%, respectively [7]. The technology has also shown good results in the treatment of post-traumatic stress. It allows a person to be transported back to the moment when they experienced psychological trauma. This helps them understand the nature of their fear, its cause, and find ways to cope with it. The same applies to childhood trauma [19].

Furthermore, according to sociological studies conducted by Russian researchers, the level of life satisfaction among people with disabilities remains low and shows signs of instability. At the same time, their dissatisfaction with the material aspects of life is compounded by an even higher

level of dissatisfaction with the existing opportunities for realizing their life strategies. Over a long period, the emotional state of people with disabilities is characterized by heightened anxiety, pessimism, and uncertainty about the future. Despite having relatives, friends, and acquaintances, many of them feel lonely or neglected. Factors that significantly improve the social well-being of people with disabilities in middle age include

the opportunity to engage in work activities [5]. The innovative capabilities of VR technologies, combined with a brain-computer interface, could address this challenge in the future.

Possible applications of immersive technologies depending on the type of health impairment are summarized in Table 1 for clarity.

Table 1

Areas of application for immersive technologies depending on the type of health impairment

Types of health impairments	Areas of application for immersive technologies		
	Education	Information	Entertainment
For people with musculoskeletal and mobility impairments	Visiting virtual museums, historical sites (such as Ancient Rome or the Egyptian pyramids), scientific laboratories, or participating in geographical expeditions that are physically inaccessible. This breaks down the barriers imposed by a wheelchair or limited mobility		Active participation in games and simulators requiring physical movement (sports, dancing, adventures) that are impossible in real life. VR allows users to "run," "fly," and "swim," providing physical and emotional sensations that would otherwise be inaccessible. Wheelchair users can experience hiking through the mountains, participate in virtual sports competitions, or play exciting games such as Beat Saber and Job Simulator using adaptive technologies, such as the WalkinVR Driver. For users with fine motor skill challenges, the integration of voice recognition technology allows them to control interfaces without using their hands
For people with visual impairments	Haptic feedback devices (such as vibrating gloves) simulate the sensation of touching objects, allowing users to explore complex shapes and models "by touch," converting visual information into tactile feedback. For example, haptic controllers with feedback can be used to explore complex shapes and models (such as molecular structures or sculptures)	Echolocation technologies in VR help explore virtual space. Audio description and 3D sound in virtual spaces allow users to "hear" a city's architecture, navigate a virtual museum using voice prompts, or receive information about objects through their audio descriptions	Special audio games and simulations where spatial sound perception plays a key role (such as detective quests or musical adventures) provide a full-fledged gaming experience. VR games specifically designed for the blind use headphones and controllers so that the user can feel as though they are in another world, navigating by sound
	Aromatic effects (olfactory technologies) in virtual reality can become a key channel of information for blind users and a powerful tool for creating reality, compensating for the absence of visual cues. For example, scents can convey additional information about works of art to blind people (the so-called Proust phenomenon). Modern developments, such as the Neuralink neural interface, may in the future be able to transmit visual images directly to the brain, bypassing the non-functioning visual system		
For people with hearing impairments	Any virtual content (lectures, tours, instructions) can be provided with subtitles integrated directly into the field of view or accompanied by visual cues. This creates a "seamless" and comfortable environment for perception		Games and entertainment apps can emphasize visual effects, haptic feedback from controllers (simulating vibrations from explosions or footsteps), and the conversion of audio signals into visual cues, ensuring full immersion. Some games are designed with the ability to convert audio to text
For individuals with cognitive impairments (ASD ¹ , ADHD ²), mental disorders, and psychological trauma	Creating controlled, predictable, and calm learning environments where social skills and scenarios (such as going to the store or a job interview) can be practiced without the sensory overload of the real world	VR technologies are used for therapy (e.g., exposure therapy for phobias or PTSD ³), allowing users to safely and gradually confront their fears and learn to manage their reactions to them	Relaxing virtual worlds help relieve stress and anxiety, serving as a form of digital relaxation, which is particularly important for a group characterized by heightened anxiety and feelings of loneliness
Versatile and futuristic solutions for people with various health conditions	Haptic feedback, such as the further development of exoskeletons and gloves, will make walking, flying, and interacting with the virtual world feel realistic, adding a new level of immersion for all users. Developments in brain-computer interfaces (BCIs) and eye-tracking open up fundamentally new possibilities for controlling VR systems for people with severe forms of paralysis (e.g., cerebral palsy or multiple sclerosis)		

¹ ASD — autism spectrum disorder.

² ADHD — attention-deficit/hyperactivity disorder.

³ PTSD — post-traumatic stress disorder.

The development of immersive technologies, including haptic feedback devices, has the potential to improve the quality of life for a large number of people. According to Rosstat data [8], as of December 31, 2023, there were 75.5

people with disabilities per 1,000 population in the Russian Federation, including children with disabilities. The distribution of people with disabilities by age in the Russian Federation as of January 1, 2023, is shown in Figure 2.

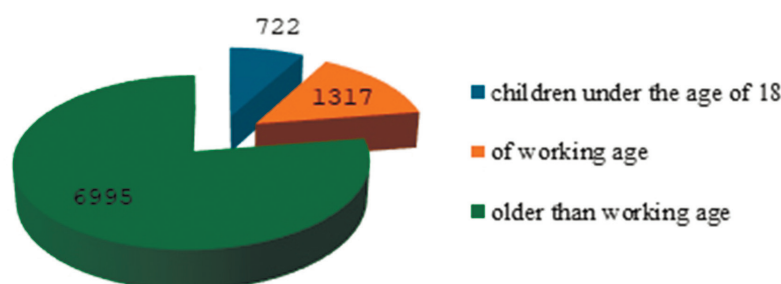


Fig. 2. Distribution of people with disabilities by age in the Russian Federation as of January 1, 2023, thousands of people*

According to data from the Federal State Statistics Service [8], as a result of a comprehensive survey of living conditions in 2022, only 7.9% of respondents among people with disabilities aged 15 and older assessed their ability to lead an active lifestyle. The remaining respondents

are unable to lead an active lifestyle because their health and/or age prevents them from doing so (86.7%) or because they have no interest or desire to lead an active lifestyle (5.4%). For greater clarity, the results are presented in Figure 3.

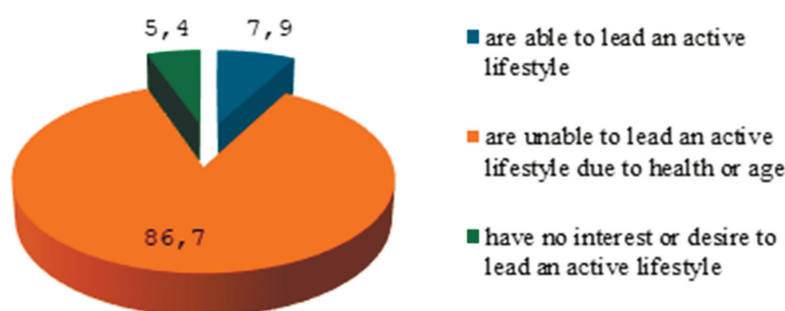


Fig. 3. The ability to lead an active lifestyle for people with disabilities aged 15 years or more, %**

These results confirm the need to increase interest in an active lifestyle and overall quality of life among people with disabilities, including through the use of virtual reality technologies. According to researchers [18], the decreasing cost of virtual reality headsets (HMDs) and real-time VR tracking equipment may soon lead to their widespread adoption in homes around the world.

A study on the use of immersive technologies in Russia for people with disabilities yielded data that identified strengths and weaknesses, as well as opportunities for their application and threats that medical centers and end users with disabilities may face. Based on the data obtained, a SWOT matrix was constructed, as presented in Table 2.

Conclusion

Thus, we have determined that the main barriers to the adoption of immersive technologies in the Russian Federation remain the failure of equipment to meet technical and user requirements, high cost, a lack of content

and specific equipment functionality, and a shortage of qualified developers and medical personnel with the necessary competencies. At the same time, the growing interest of developers and investors in addressing these challenges opens up new horizons for people with disabilities in terms of active living, rehabilitation, education, and entertainment. Virtual reality technologies have the potential to transform how people interact with the world and can make it more inclusive and accessible, while improving the satisfaction and quality of life for people with health impairments.

Authors' contributions:

Ruslan Antonovich Vakhrushev — literature search and analysis (technical information);
Sergey Nikolaevich Khalimanenko — literature search and analysis (medical information);
Yana Alekseevna Cherezova — article formatting, statistical data processing;
Ulyana Alekseyevna Yaksina — Literature Search and Analysis (Mental Disorders).

* See the Rosstat website: URL: rosstat.gov.ru (accessed: 09/15/2025).

** See the Rosstat website: URL: rosstat.gov.ru (accessed: 09/15/2025) (based on data from the Comprehensive Survey of Living Conditions).

Table 2

SWOT Analysis of the Application and Development of Virtual and Augmented Reality Technologies for People with Disabilities in Russia

<i>Strengths:</i> · realistic imagery; · intuitive controls; · positive results from the use of VR tools for rehabilitation and treatment; · real-time interaction; · availability of some forms of haptic feedback	<i>Weaknesses:</i> · equipment that does not meet technical and user requirements; · high cost of tools; · lack of content and specific equipment functionality; · lack of qualified developers and medical personnel with the necessary skills; · low patent activity; · insufficient publication activity by domestic researchers; · potential negative health effects
<i>Opportunities:</i> · high innovation potential; · growing investor interest in further development; · growing interest from users and healthcare organizations; · desire for full immersion in virtual reality	<i>Threats:</i> · lack of information on current usage results; · unpredictability of external factors; · lack of research on long-term health effects

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