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The state and prospects of using virtual reality technologies in sports: a brief review

B. R. Atlasov[1], A. K. Selskiy[2]

[1]Russian International Olympic University, Sochi, Russian Federation
[2]National Research University «Higher School of Economics», Moscow, Russian Federation

Abstract

The article examines the current state of the global virtual and augmented reality (VR/AR) technology market in sports, noting its growth, although slower than previously expected. Special attention is paid to the Russian market, where the development of VR technologies in sports lags behind world leaders such as the United States, EU countries and China, but at the same time has significant potential for growth. The analysis of current trends and prospects for the use of VR/AR in sports training, with an emphasis on martial arts, in particular jiu-jitsu, is carried out. The problems and limitations hindering the development of the use of VR technologies in sports training are outlined.

Keywords: virtual reality in sports, sports training, sports innovation, sportstech, digital sports, digital transformation of sports, immersive training, martial arts, jiu-jitsu

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Состояние и перспективы применения технологий виртуальной реальности в спорте: краткий обзор

Б. Р. Атласов[1], А. К. Сельский[2]

[1]Российский международный олимпийский университет, Сочи, Российская Федерация

[2] Национальный исследовательский университет «Высшая школа экономики», Москва, Российская Федерация

Аннотация

В статье рассматривается текущее состояние глобального рынка технологий виртуальной и дополненной реальности (VR/AR) в спорте, отмечается его рост, хотя и более медленный, чем ожидалось ранее. Особое внимание уделено российскому рынку, где развитие VR-технологий в спорте отстает от мировых лидеров, таких как США, страны ЕС и Китай, но при этом имеет значительный потенциал для роста. Проведен анализ современных тенденций и перспектив применения VR/AR в спортивной тренировке, с акцентом на боевые искусства, в частности, джиу-джитсу. Обозначены проблемы и ограничения, препятствующие развитию применения VR-технологий в спортивных тренировках.

Ключевые слова: виртуальная реальность в спорте, спортивная подготовка, спортивные инновации, спорттех, фиджитал спорт, цифровая трансформация спорта, иммерсивное обучение, единоборства, джиу-джитсу

Introduction

Digital technology in general and particularly virtual reality (VR) systems are increasingly permeating the daily lives of various cohorts of individuals. IT solutions provide support in all types of activities and at all stages of life; the processes of education and sports training are no exceptions.

Educational applications, interactive modules, and other soft- and hardware products allow to build more effective learning algorithms, making it easier for learners to acquire new information, find answers to their enquiries, and enjoy a vast variety in their studies, even in routine tasks.

The training process in sports, structured as a system of exercises, provides a form of learning representing a "pedagogically organized process of managing athletes' development (their sport results improvement)"[1]. So, an embedding of digital educational products into the sports training process can stimulate the acquisition of new competences, reinforce the development of necessary skills, as well as increase the trainees' involvement through more interactive and engaging learning formats.

At the same time, existing products in this field typically cover a narrow range of highly commercialized sports, leaving a gap for most disciplines. In this article we explore the prospects for developing and implementing a VR simulator initially aimed to enhance training in jiu-jitsu, with a potential to be further expanded to other martial arts. We believe that the integration of such a virtual reality system into the training process will accelerate the sport training process in jiu-jitsu, improve its quality, and attract new individuals as athletes.

Materials and methods

The primary method used for this article's preparation was a qualitative analysis of secondary sources reflecting various aspects of the integration of virtual and augmented reality (VR/AR) technologies in sports. An important criterion for forming the literature review was the study of the application of VR in a wide range of contexts, both within the sports industry and beyond. Special attention was paid to finding evidence of the positive impact of training in virtual reality on sports performance. In addition, five semi-structured customer development interviews were conducted among jiu-jitsu athletes and coaches, with the help of one of the article's authors, the head of a Brazilian jiu-jitsu sports school.

VR/AR technologies in sports as an emerging market

Nowadays, virtual and augmented reality (VR/AR) technologies are primarily known due to the widespread promotion of consumer solutions by global Big Tech companies such as Apple and Meta (forbidden in Russia). The development of metaverses, often grouped with VR and AR in modern research as part of the new "immersive reality"technologies, is also gaining attention [2].

However, the industrial application of VR and AR is equally important, where corresponding IT solutions enable the improvement of corporate approaches to employee training, design, and management of production processes, as well as equipment maintenance. This is becoming possible through realistic simulations of processes and the visualization of production operations. AR solutions, for instance, provide visual cues and step-by-step instructions during technical maintenance and repair work, reducing costs and accelerating business processes. Such corporate VR/AR solutions are being actively developed in Russia, where the total revenue of startups in this segment grew by 83% in 2022 compared to 2021 [3].

The global market for VR and AR in sports is growing at a significantly slower pace. According to a Wise Guys Reports (2024), the market size has increased from \$5.19 billion in 2023 to $5.75 billion in 2024. It is expected to reach 13.02 billion by 2032, with an average annual growth rate (CAGR) of 10.76% [4]. This is a stark contrast to the optimistic projections made during the COVID-19 pandemic, when sports competitions and training temporarily most commonly shifted to remote and virtual formats [5]. Nevertheless, interest in this market segment remains strong worldwide. VR systems have already become widespread in many sports, including car racing, baseball, biathlon, bobsleigh, boxing, golf, skiing, skateboarding, snowboarding, tennis, fencing, and many others. Developments in VR technology applications are being pursued by several global leaders in the sports industry, including Red Bull and Nike [6]. It is worth noting that VR-based solutions can target both athletes and fans. Table 1 summarizes the main areas of VR use in sports.

Among the international IT solutions in the field of VR for sports notable examples include STRIVR (American football), HomeCourt (basketball), VR Motion Learning (tennis), Rezzil (soccer), ICAROS (fitness), and others. The Big Tech giants are also pursuing developments in this area. In particular, Mark Zuckerberg, co-founder of Meta Platforms Inc (forbidden in Russia), mentioned the VR developments in jiu-jitsu during a podcast with a renowned sports commentator Joe Rogan [7].

The development of VR technologies in Russian sports lags behind the US, EU, and China. During the preparation for the "Games of the Future"held in Kazan in 2024, the possibility of organizing competitions in virtual reality was considered as a part of phygital sport, but it was ultimately not implemented [8]. This could happen due to a

Table 1: Main applications of virtual reality technology in sports

No	Area of VR use	Target Audience
1.	Interactive watching of sports event broadcasts	Fans
2.	Accurate recording and subsequent playback of athletes' technical actions for analysis and improvement	High-performance athletes and amateurs; coaches
3.	Improving tactical skills in team sports by recording player actions during matches and analyzing them from the player's perspective	Athletes and coaches (team sports)
4.	Simulating potentially dangerous situations without physical contact (e.g., heading a ball in soccer) to reduce injury risks during training	Athletes and coaches
5.	Simulating competitive matches to immerse athletes in the psychological state of real tournaments and train psychological resilience	Athletes and coaches
6.	Diversifying sports training through gamification	Youth athletes

lack of spectacle in such tournaments' broadcasts and an absence of domestic or friendly (non-affected with the sanctions imposed on Russia) software and hardware solutions. Indeed, a 2023 study of the Russian sports tech market by Innopraktika identified only one domestic VR product for sports: the Boxglass VR solution for fencing. There is also ongoing development of training VR systems by the Russian Airsoft Federation and the Russian Boxing Federation. However, overall, there are very few national VR projects for sports, and their development teams are disintegrated.

It is also important to consider existing research on the pedagogical effects of VR technologies in sports.

For example, Zhang (2024) discusses the application of virtual reality in teaching martial arts in colleges and universities. The author insists that motion capture technology allow to model the three-dimensional scene and correct students' errors in real-time. The solution descripted significantly improves the mastery of trainees and reduces the time delay compared to traditional teaching systems. The article also emphasizes the positive impact of VR on students' learning interest and motivation [9].

Richlan et al. (2023) analyzed 12 cases involving the use of virtual reality in training process, with a total of about 500 participants (ranging from 15 to 80 subjects per

case, from beginners to professional athletes). The sports covered in the study included basketball, baseball, bowling, cycling, golf, darts, karate, curling, table tennis, archery, and soccer. The results of the experiment showed that the sports performance of groups whose training process involved VR surpassed that of control groups where VR was not used [10].

Taupin et al. (2023) investigate the effects of VR training on boxing performance, particularly focusing on perceptual-cognitive skills like anticipation and decision-making. Using an eye-tracker camera and heart rate monitor during sparring sessions allowed to find that VR training may have positive transfer effects on both gaze behavior and objective performance measures in elite boxers. Subjective performance improvements were also reported, including better technical and tactical abilities [11].

The Lomonosov Moscow State University experts team (2021) compared the motor reactions and performance of professional ice hockey players and non-experienced participants using VR. The study involved 22 participants, including 13 professional hockey players and 9 non-experienced individuals. Its results indicated that professional hockey players exhibited distinct technical and tactical abilities that contribute to their superior performance, highlighting the importance of specific spatial-temporal, technical, and tactical determinants in achieving high performance in ice hockey. The study suggests that VR technology can be a valuable tool for training and enhancing the skills of both professional athletes and novices [12].

Lijo et al. (2024) discuss the use of VR in martial arts training, paying attention to such its competitive advantages as the provision of the safe learning environment, an opportunity to have detailed analysis and optimization of performance, offering personalized training regimens and customizable practice environments [13]. Thus, there are some experimental evidences supporting the potential of VR technologies to improve the effectiveness of sports training.

The potential of using VR technologies in sports training

The above mentioned analysis demonstrates the potential for VR technologies use in athletes' training, as well as an evident lack of such tools and practices in the Russian market. It should also be noted that the conclusions about the positive impact of VR simulators on sports performance can be considered implicit due to a limited number of relevant evidence-based studies.

The development of a VR tool for sports training in martial arts, for example, in jiu-jitsu, can be deemed feasible, provided that potential limitations related to the product's functionality are taken into account. In particular, to test the hypothesis about the potential demand for such an IT solution, the most suitable target audience is beginners such as individuals who have been practicing jiu-jitsu for less than six months, or those

who are completely unfamiliar with this sport.

First, their numbers are significantly higher than those of professionals in the sport, providing a broader testing sample. Second, at the minimum viable product (MVP) stage, significant investments into its development can be avoided as far as beginners are less demanding in terms of content than more experienced users, so there is no immediate need to implement costly features such as feedback tools and multiplayer modes.

Each athlete must spend a significant amount of time practicing basic movements. So, boxers practice punches on a heavy bag and shadowbox, soccer players take penalty kicks, and basketball players shoot three-pointers. In jiu-jitsu, practitioners have drills, or movements consisting of repetitive techniques.

One of the foreign VR solutions, FitXR, combines boxing and jiu-jitsu for fitness training. The boxing part focuses on reflexes, speed, accuracy, and cardio, simulating real boxing moves such as dodges, dives, and punches [14].

Problems and limitations of using VR in sports training

A software product that allows users to practice various techniques, refine skills, and engage in training sparring with opponents without the need to meet in a gym is highly appealing for martial arts. However, its implementation is complex. Features such as simulating the impact on an opponent through holds and the pressure exerted by one opponent on another remain largely unexplored. Developing these elements requires both mathematical and physical expertise from the development team, as well as significant investments, which are uncommon in the Russian sports tech market [15].

In our view, the process of innovative development in VR for sports could be accelerated by uniting the efforts of various stakeholders such as sports federations, clubs, and other organizations. From a software perspective, many processes in the virtual environment are similar, and if a corresponding product has already been created, for instance in fencing, adding the martial arts-related functionality would require significantly less financial investment and effort than creating a similar product from scratch.

It is also important to emphasize the need for further experimental research of the potential VR products impact on the effectiveness of sports training processes. Numerous researchers [9], [10], [11], [12], [13] pay attention to the significant limitations of virtual reality scalable use in sports training, including martial arts. This is related to several main reasons. First of all, premium VR equipment, such as headsets, motion sensors, and powerful computers, is rather expensive, making it difficult for many athletes and sports facilities to access. Second, the virtual environment and equipment currently cannot fully reproduce the physical sensations of the real world, such as the feeling of contact and resistance, which limits the completeness of the training, especially in martial arts. Third, a longer use of VR solutions often lead to users' discomfort and motion sickness,

such as dizziness or nausea, especially during rapid movement or rotation in the virtual environment, which is limiting the duration of training sessions. These nuances highlight that although VR has significant advantages and potential in sports training, it cannot fully replace traditional training methods at the moment.

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About the authors

Bulat Rashitovich Atlasov – Russian International Olympic University, Jungle BJJ Brazilian jiu-jitsu school, Ufa, Russia.

E-mail: *Bulatatlasovajp@yandex.ru*

Andrey Konstantinovich Selskiy – Center for Research on Advanced Competencies and Talent Development at the National Research University Higher School of Economics, Moscow, Russia. E-mail: *aselskiy@yandex.ru*

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