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VR Sports Games: An Overview

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ABSTRACT

This article provides an overview of the history of VR sports games and offers insights into the interaction and integration between real-world sporting events and VR games. Additionally, it reveals the challenges associated with VR gaming technology and VR sports games. Overall, motion-control based VR sports games blur the lines between the virtual and real sport, providing new options for participating in sports, fitness activities and competitions. They offer opportunities for individuals to explore and learn sports that may have been inaccessible to them otherwise. Furthermore, VR sports games have been increasingly integrated into international sporting events, paving the way for a new direction in the future development of both sports and video games. As computer and information technology advances, VR sports video games are creating innovative avenues for entertainment, physical exercise and sports competition.

KEYWORDS

VR; video games; virtual sports; international sporting events; challenges

Virtual reality (VR) refers to ‘a set of images and sounds, produced by a computer, that seem to represent a place or a situation that a person can take part in.’¹ More specifically, in the field of video gaming it means a computer-generated simulated environment projected in near-eye displays or in a head-mounted display (HMD) system, which seems like reality to the person exploring and interacting with it using pose tracking and controllers. VR technologies emerged in the 1960s alongside the advent of the first generation of computers. Early examples are the Telesphere Mask (1960), invented by American filmmaker Morton Heilig (1926–1997), and the Sword of Damocles HMD system, created by computer scientist Ivan Sutherland and his students at the University of Utah in 1968.

Over the subsequent two decades, the technology underwent steady development within research institutions and technology companies in the U.S. and found applications in diverse fields, being used for scientific research and military training purposes. A notable example is the Large Expanse, Extra Perspective (LEEP) display system developed by Eric Howlett in 1979, which NASA’s Ames Research Center employed in a Virtual Interactive Environment Workstation in 1985. In the second half of the 1980s, led by the EyePhone created by VPL Research, a Californian tech company founded by American computer scientist Jaron Lanier, commercial VR systems began to attract public attention. Virtual environment-themed software and

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games, such as the racquetball game running on the VPL EyePhone and the ski simulator built by Japanese information technology and electronics corporation NEC, were created to test these pioneering systems. In the late 1980s commercial VR HMDs began to emerge, and by the early 1990s VR gaming had gained public attention with the release of pioneering VR arcade systems and HMDs for home gaming consoles and PCs. Despite this early interest, VR gaming was hindered by technical limitations, high costs and a lack of support from game publishers. It was not until the 2010s that VR HMDs and VR games truly took off and started to achieve mainstream popularity.

In response to the surging VR gaming industry and its rapidly expanding market, academia began to delve into this novel domain, generating a significant body of research across diverse disciplines and perspectives. Much of the research focuses on the function of VR games as tools for health assessment, promotion, therapy and rehabilitation²; some published works analyse the educational value of VR games,³ while others focus on game design and player experience.⁴ Additionally, several studies have examined the frequently observed issue of motion sickness in VR games.⁵ Unlike previous and current publications that either focus on the utilisation of VR games in different settings and for different purposes or concentrate on software- and hardware-related issues that affect game design and user experience, this article exclusively focuses on a specific genre of VR games: sports-themed titles. It showcases the influence of VR technology on video game design and innovation, illustrating how VR games have merged with traditional sports, creating innovative avenues for entertainment, physical exercise and sports competition. The objective is fourfold: (1) to review the history of VR sports games, from the birth of commercial VR games in the late 1980s to the present day; (2) to understand the strengths and limitations of VR sports games in terms of gameplay and user experience; (3) to provide insights into the interaction and integration between real-world sporting events and VR games; (4) to reveal the challenges associated with VR technology and VR sports games.

The Rise of Commercial VR HMDs and Dedicated VR Games

Dedicated VR gaming systems made their debut in 1987, when Nintendo and Sega introduced VR accessories for their home video game consoles: the Famicom 3D System for the NES and the Scope 3-D Glasses for the Sega Master System. Both devices could display a stereoscopic image when paired with compatible games, utilising binocular vision to enhance the perception of depth. In 1991, UK-based W Industries (later renamed Virtuality), founded by Jonathan Waldern, launched the world's first commercial VR arcade gaming systems, the Virtuality 1000CS and 1000SD.⁶ With a staggering price tag of £25,000, the 1000CS system consisted of a HMD headset which contained a pair of 300x200-pixel Sony LCD screens, a hand-held controller and an Amiga 3000 computer.⁷ It used magnetic tracking technology to determine the position of the headset and controller. Players stood in a waist-height ring to play real-time rendered 3D first-person shooter, puzzle or adventure games. The 1000SD featured a cockpit-like cabinet for players to sit in and use fixed joysticks and pedals to play flight simulation, car racing or robot combat games.⁸

The groundbreaking system was succeeded by the *Virtuality 2000 Series* in 1994, which featured a newly designed headset that was smaller and lighter, with higher resolution (800x600 per screen) and an improved lens system that offered a wider field of view. In addition to 3D shooting, adventure and racing games, the new system featured *Virtual Boxing* – a 360-degree sports action game played against a computer-controlled boxer or another player through network-linked cabinets. Players stepped into the ring platform, put on the headset and used one hand to hold the cabinet for balance while punching the opponent with the hand holding the joystick. This was arguably the first commercially available motion-controlled VR sports game in history, paving the way for a new era of immersive and engaging virtual sports experiences.

In response to the growing interest in VR video gaming sparked by the *Virtuality* series, major players in the video game industry promptly introduced their own VR systems. Sega and Atari developed the *Sega VR*, *Virtua Visor* and *Jaguar VR* for their *Mega Drive/Genesis*, *Saturn* and *Atari Jaguar* home consoles respectively. However, they ultimately abandoned the commercialisation of these devices due to inherent technical constraints and safety concerns.⁹

Sega's *Mega Visor Display* (1994) and Nintendo's *Virtual Boy* (1995) were the only commercially available game-oriented VR systems at the time. The former featured a lightweight HMD, real-time 3D graphics and head-tracking technology, and was specifically designed for the VR-1 indoor amusement rides in Sega's theme parks and for Sega arcade rail shooter games. It proved more successful than Nintendo's effort; the \$179.99 *Virtual Boy* failed to attract consumers due to its monochrome graphics, lack of head-tracking and poor ergonomics. It was discontinued less than a year after release, with 770,000 units sold worldwide – making it Nintendo's least successful console at the time.¹⁰ Nevertheless, the system should be remembered for its pioneering role in bringing VR sports games to players' homes. The console came bundled with *Mario's Tennis*, and of the twenty-two officially released games, seven were sports-themed, encompassing tennis, bowling, golf, squash, baseball and fishing.

In addition to these dedicated VR gaming devices, the mid-1990s saw the arrival of a number of commercial VR HMDs. These included the *VictorMaxx StuntMaster* (1993) and *CyberMaxx* (1994); *Virtual IO's i-glasses* (1995), which worked with TVs and computers to create a stereoscopic view; and the more technically advanced *VFX1 Headgear* (1995) produced by *Forte Technologies* for the PC and designed to be paired with 3D first-person shooter, adventure, role-playing and flight simulation games.

However, the VR trend gradually faded away in the latter half of the 1990s as the gaming industry and community shifted focus to the Internet, 3D and online multi-player gaming.¹¹ The discomfort and physical strain associated with using HMDs, including eye fatigue, pressure exerted by the headset on the face, head and neck, and in particular motion sickness. The stereoscopic 3D content delivered by HMDs is more realistic and immersive than the monoscopic images displayed on monitors, and thus generates vection: the brain perceives movement even though the player is physically stationary. This leads to conflict between visually perceived movement and the vestibular balance system's sense of movement, resulting in symptoms such as dizziness, nausea and headaches, which contributed to the decline of VR gaming.¹² Worldwide VR sales reached an estimated \$135 million in 1995, but the technology remained stagnant in subsequent years, leading some IT industry commentators to

describe the latter half of the 1990s as a ‘VR winter’.¹³ By 1999, the number of articles on VR published in the business press had declined to less than half of the 1995 total.¹⁴

Despite waning public interest, VR HMDs managed to persist throughout the late 1990s and the 2000s, albeit at a slower development pace.¹⁵ Alongside professional systems for military, engineering and medical use, home entertainment devices continued to evolve. These included Sony’s Glasstron family of multimedia headsets (1996–1998) and the PUD-J5A (2002) for PlayStation 2, the Philips Scuba Visor (1998), the Olympus Eye-Trek series (1990–2001), the IIS VFX3D (2000), the IO Display Systems i-glasses (2003), the eMagin Z800 3DVisor (2005) and the Sensics piSight (2006) with OLED displays, as well as the lightweight Vuzix iWear VR920 with a compact design similar to eyeglasses (2009). However, none of these products presented a significant technological breakthrough, thus failing to bring about substantial change in the user experience. Additionally, compared to 3D gaming on the newly emerging large-format, high-resolution LCD displays, the low-resolution graphics and narrow field of view (FOV) of these HMDs made them less appealing to gamers. Also hindered by their high cost, ranging from \$400 to \$1,800, and the lack of compatible games and media content, they failed to gain mainstream appeal and remained a niche choice.

Oculus Rift, the Game Changer

A watershed moment in the VR market arrived in 2013 when California-based Oculus VR, founded by American entrepreneur Palmer Luckey, released the Oculus Rift Development Kit 1 (DK1). The headset featured a 7-inch LCD screen with 640x800 pixels-per-eye resolution and made a significant leap in FOV, spanning 90 degrees horizontally and vertically, almost double the coverage of most previous commercial HMDs. Head motion tracking was realised through a combination of three-axis gyroscopes, accelerometers and magnetometers, providing 3DoF tracking capabilities. With an accessible price of \$300, precise, low-latency position tracking, higher resolution and wider FOV, the Rift DK1 transformed the VR experience and quickly attracted the attention of the IT industry and the gaming community. In less than a year following its release more than 75,000 DK1 units were sold worldwide, a significant commercial success that pointed to the long-awaited resurgence of VR.¹⁶

In March 2014, Facebook entered into an agreement to acquire Oculus for \$2 billion.¹⁷ After the deal became official in July that year, Oculus unveiled the Rift DK2. This upgraded device supported 6DoF (3-axis rotational and 3-axis positional tracking) and featured an OLED display with a higher resolution and refresh rate, a significantly lower pixel response time and a near-infinite colour contrast ratio, further enhancing the already groundbreaking VR experience. By mid-2015, more than 175,000 DK1 and DK2 units had been shipped globally.¹⁸ The finished product, the Oculus Rift CV1, was eventually launched in March 2016 together with 30 compatible games accessed through the online Oculus store, complemented by the release of Oculus Touch wireless motion controllers in December.

Facebook founder and CEO Mark Zuckerberg said he believed that virtual reality was a ‘transformative and disruptive technology’ that might ‘change the way we work, play and communicate’.¹⁹ The Rift’s launch titles showcased how VR had revolutionised the way video games are developed and played. These games were either purposely designed or modified with the objective of creating an immersive 3D environment while minimising visually induced motion sickness. Each game was classified into one of three comfort levels: intense (those with a fast-moving camera, such as racing, first-person shooters and space combat games); moderate (those with a slow-moving camera, such as adventure and platform games); and comfortable (those with a fixed camera, such as third-person perspective puzzle, real-time strategy, simulation and role-playing games).

The initial line-up consisted of three custom-designed sports games: *VR Sports Challenge*, *VR Tennis Online* and *The Climb*, all at moderate comfort level. *VR Sports Challenge*, developed by Sanzaru Games and published by Oculus, included four sports: basketball, baseball, ice hockey and American football. The actions were rendered in first-person perspective. To reduce motion sickness, gameplay focused on hitting or throwing a ball from a fixed position, rather than allowing the player to move around the field as in traditional sports games. For example, in the basketball game, the view automatically switched between team members when the ball was passed. Players moved their hands up and down to dribble the ball and swung their arms in the air to pass or shoot. In ice hockey, the player initially took on the role of the goalie to block shots. After making enough saves, the game automatically switched to the winger’s perspective, with players shooting by swinging their arm as if using a hockey stick.

In contrast, *VR Tennis Online*, produced by Japan’s COLOPL, adopted a third-person, fixed-camera perspective. Players remained stationary and swung their arm to hit the ball, akin to the mechanics of Wii tennis games. *The Climb*, developed by German company Crytek, used the HMD and Oculus Touch controllers in an innovative way, providing a unique virtual sports experience: players stood in a fixed position and used hand movements to climb up a rock cliff while experiencing mountain-top views in a first-person perspective (see [Figure 1](#)).

Assisted by these games, over 400,000 units of the Oculus Rift were sold in its first six months.²⁰ By the end of 2016 the Oculus Store had over 120 free and paid titles available, and by July 2017 this had surged to 500. Four games had grossed over \$1 million, with *The Climb* leading.²¹ Three months later the number of games in the \$1 m club had more than doubled, reflecting the fast-growing popularity and success of the Oculus Rift and its ecosystem.²²

The Rift single-handedly reactivated the VR entertainment market. Major PC vendors and software companies in the U.S. and Asia soon followed suit, launching competing HMDs and software platforms.²³ These included the Razer OSVR (2015–2016), which ran on the OSVR software; the HTC Vive (2016), operating on HTC’s Viveport and Valve’s SteamVR software platforms; Sony’s PlayStation VR (2016) for PlayStation 4; and the HP VR1000 (2017), Dell Visor (2017), Samsung Odyssey (2017) and Lenovo Explorer (2017), supporting both the SteamVR and Windows Mixed Reality platforms.



Figure 1. *The Climb* screen shot.
Source: Courtesy of Meta.com.

1.4 million VR HMDs were sold worldwide in 2016, led by the PlayStation VR, HTC Vive and Oculus Rift in terms of sales and popularity.²⁴ In 2017 global shipments of VR devices more than doubled to 3.7 million units, with the PlayStation VR alone selling 1.7 million.²⁵ The ensuing years saw steady growth in the VR market. Dozens of new headsets from various manufacturers were launched each year, including the Pico G2 (2018), Fujitsu FMVHDS1 (2018), Pimax 5k (2018), Valve Index (2019), Varjo VR (2019) and Acer OJO 500 (2019). Oculus also followed up with the stand-alone Oculus Quest (2019), which runs on a mobile-based hardware and Android-based operating system, and the PC-powered Oculus Rift S (2019), both of which allow users to see their real-world surroundings while wearing the headset, using built-in cameras.²⁶

At the same time, more and more games intentionally crafted for VR were being made available on the SteamVR, Oculus Store (replaced by Meta Store in 2022) and PlayStation VR platforms. By 2020 combined VR hardware and software revenue had reached an estimated \$3.2 billion, with more than 100 VR games earning \$1 million or more.²⁷ With average annual growth of 42 percent, the VR user base was also expanding rapidly. In 2019 there were approximately eight million active headsets; by 2021 there were over 20 million, and by 2023 there were 36 million.²⁸

In built-for-VR games the FPS genre has been the most popular, followed by action-adventure and simulation games, with sports games occupying a smaller niche. For instance, as of 2020, six of the top ten bestselling VR games across all platforms were FPS games.²⁹ Of the top 50 SteamVR apps of 2023 by gross revenue, 21 were FPS, 14 were action-adventure and 7 were simulation games. Only four sports-related titles – Beat Games' *Beat Saber* (2018), Mighty Coconut's *Walkabout Mini Golf* (2020), Better Than Life's *Kayak VR: Mirage* (2022) and Buckethead Entertainment fighting game *RUMBLE* (2022) – made the list.³⁰

Unlike traditional sports video games played from a third-person perspective, which allow players to oversee the event as if watching a live broadcast, VR sports games have entirely different gameplay mechanics and control methods. They are usually played from an immersive first-person perspective, placing players directly on the field to experience the actions as if they are the athletes. Since players wearing headsets cannot see their real-life surroundings during gaming, these games are typically designed to be played while standing in a confined play area, which can be pre-defined and calibrated with the HMD's built-in cameras. This is to prevent players from losing their balance or colliding with obstacles in the room, such as walls, furniture and people, thus avoiding potential injuries.

Additionally, despite advancements in head tracking, display and 3D rendering technologies, visually induced motion sickness remains a major barrier for VR games in general, and fast-paced sports games in particular. Therefore, many VR sports games are based on individual sports with comparatively slow actions, such as archery, darts, bowling, golf, pool and racquet sports, with gameplay centred on mimicking upper body movement. Examples include Pixel Edge Games' *Racket Fury: Table Tennis VR* (2017), One Hamsa's *Racket NX* (2019), Mighty Coconut's *Walkabout Mini Golf* (2020), Golf Scope's *GOLF+* (2020), For Fun Labs' *Eleven Table Tennis* (2020), ForeVR Games' *ForeVR Bowl* (2021) and *ForeVR Darts* (2021), Appnori's *All-In-One Sports VR* (2021), Pixelworks' *Black Hole Pool VR* (2021) and Mikori Games' *First Person Tennis* (2022) (see [Figure 2](#)).

Alzan Studios archery game *Holopoint* (2020) is an excellent illustration of how VR sports games differ from those played on a TV or computer monitor with gamepads. Players stand in a fixed spot and extend their arms to mimic shooting a bow (see [Figure 3](#)). They need to turn their head and body around to observe and shoot airborne cubes, samurai and ninjas that appear from a 360-degree range of directions

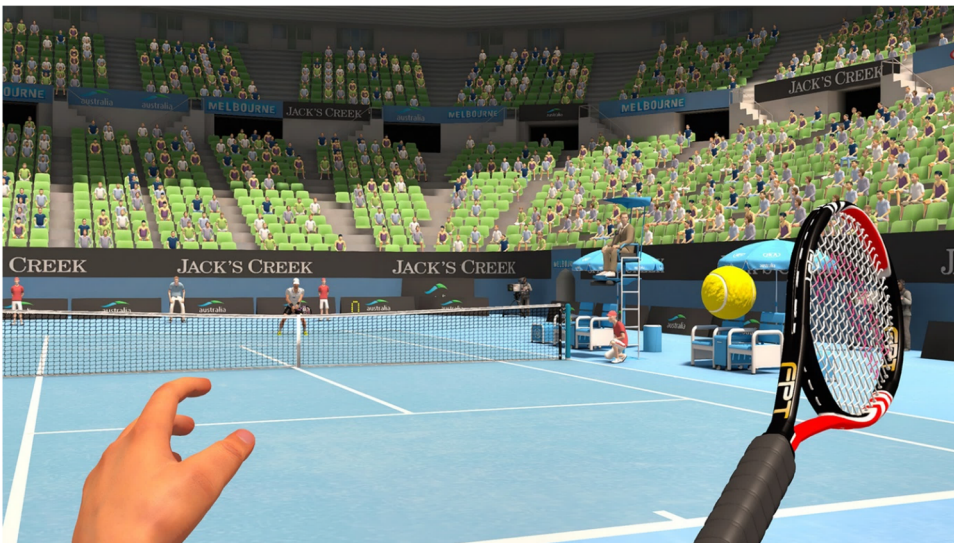


Figure 2. *First Person Tennis* screen shot.
Source: Courtesy of Meta.com.

and at different heights, all while ducking and dodging to avoid incoming projectiles. When the game's difficulty level increases, players need to shoot waves of targets in fast-paced action, turning the gameplay into an intense full-body workout.

When it comes to team sports like baseball, soccer and basketball, the gameplay usually centres on hitting, shooting or throwing the ball from a fixed position, rather than offering a full competition experience where players have complete control over on-screen characters, including the ability to sprint, tackle opponents in fast-paced situations and make various tactical decisions during play. Take StatusPRO's well-received *NFL Pro Era* (2022) as an example. The game is the first NFL- and NFLPA-licensed VR title, featuring all 32 NFL teams and stadiums. It gives gamers the quarterback's perspective, focusing solely on offensive play with a strong emphasis on throwing accuracy. The sequel, *NFL Pro Era II* (2023), retains the core game mechanics of its predecessor while introducing new features and improvements, including a career mode that enables players to take their team to the Super Bowl, a 'Coach's Confidence' rating system for unlocking new play calls and abilities, additional online head-to-head multiplayer modes, enhanced player movement and AI, as well as improved graphics. Similarly, Ivanovich Games' *Final Soccer* (2022) only offers skill-based scenarios instead of simulating a full soccer match. Players can either be the goalkeeper, holding a controller in each hand to catch the ball, or take penalties or free kicks by attaching one controller to their foot.

First-person perspective rhythm-action/fitness games have emerged as some of the most popular VR experiences. Through innovative design, they showcase how VR headsets and motion controllers can be used to deliver engaging gameplay while also providing fitness benefits to players. *Beat Saber* is the undisputed pioneer and leader in this genre. The game lets players stand in a fixed position facing a tunnel. The goal is to wield the two controllers like a pair of red and blue *Star Wars* lightsabers,



Figure 3. *Holopoint* poster.
Source: Courtesy of Meta.com.

cutting through incoming cubes of the corresponding colour while avoiding obstacles by ducking or leaning to the side, with all the action synchronised with the pace of the music (see Figure 4). As one of the most successful VR games to date, it is played by 1.47 million monthly active users and had grossed over \$255 million in revenue as of 2022.³¹

BoxVR (2017), another popular fitness game by FitXR, adopts the same game mechanics, with players following the music to punch, block or evade incoming targets. It also features a real-time calorie counter and a timer to display the duration of the workout and the energy burned, estimated based on the user's weight and the intensity of the session. The gameplay can be quite physically demanding, as players execute a continuous stream of punching moves at a rapid pace. Other examples of this kind include Within Unlimited's *Supernatural: Unreal Fitness* (2020), Odders Lab's *OhShape* (2020), Odders' *Les Mills BODYCOMBAT* (2022) and Five Mind Creations' *PowerBeatsVR* (2023), all of which use a similar approach to provide engaging music-guided calory-burning workouts.

Boxing is another sport that translates well into VR gaming, with Survios' *Creed: Rise to Glory* (2018) and Sealost Interactive's *The Thrill of the Fight* (2019) standing out as the most popular titles to date. In both games, players are fully immersed in the boxing ring, using their entire body to execute a variety of punching, dodging and footwork techniques against computer-controlled opponents. The gameplay is confined within a restricted play area marked with coloured boundaries, designed to



Figure 4. *Beat Saber* flyer.
Source: Courtesy of Meta.com.

match the room scale. Playing the game in a larger room gives players more in-game manoeuvring space in the ring, resulting in a highly realistic boxing experience.

In recent years, advances in mixed reality (MR) technology have opened up new possibilities for VR sports games. With the emergence of new-generation HMDs that support MR well, players can now interact with virtual objects in their real-world environment. One notable example of this is Resolution Games' *Racket Club* (2023). The game is specifically designed for living room play, requiring a minimum space of 6.5 x 6.5 feet. It offers single and doubles multiplayer options and can be played in either MR or VR mode. In MR mode, the virtual court is overlaid onto the living room, which means that players can see their virtual opponents, the court and the real surroundings at the same time. This allows them to move around the court and swing their arms without worrying about obstacles such as furniture or teammates (see [Figure 5](#)). It also helps minimise visually induced motion sickness. As MR technology continues to evolve, we can expect to see more innovative titles that seamlessly blend virtual and real elements to create an immersive, engaging and enjoyable virtual sports experience.

Integration with Real Sporting Events

For a long time, the gaming industry has been dominated by major game publishers and developers in the U.S. and Japan, notably Microsoft, Nintendo, EA, Sega, Sony and Take-Two Interactive, with North America, Japan and Western Europe the major gaming markets. Since the turn of the century, with the rise of China, South Korea, India, Indonesia and other emerging economies, Asia has grown into the world's biggest video game market. China has taken the lead, reaching \$42.6 billion in sales in 2023 and forecast to surpass \$57 billion by 2027.³² Chinese game companies like



Figure 5. *Racket Club* screenshot.
Source: Courtesy of Resolution Games.

Tencent, miHoYo and NetEase have also emerged as the new powerhouses in the global gaming industry.

In the past two decades, alongside the growth of the gaming market and industry, and notably due to the efforts of gaming companies, esports organisations and participants in China and South Korea, Asia has evolved into a global gaming and esports hub. Since the mid-2000s, newly established not-for-profit esports organisations and national esports federations in Asia have been especially active in promoting competitive gaming as a sporting activity and have successfully integrated esports into multi-sports events organised by regional and international sports federations. As early as 2007, with the efforts of the Macau E-Sports Federation and the Olympic Council of Asia (OCA), esports was included in the 2nd Asian Indoor Games (AIG) in Macau.³³ National teams from China, Iran, India, Kuwait, Mongolia, Qatar and Uzbekistan competed in *NBA Live 2007* (2006), *FIFA 2007* (2006) and *Need for Speed Most Wanted* (2005) at the Macau East Asian Games Dome.³⁴ Esports was then included in subsequent AIGs in Vietnam (2009), South Korea (2013) and Turkmenistan (2017), attracting wide media coverage and public interest.³⁵

Subsequently, in 2018 the OCA cooperated with the Indonesian Esports Association (IeSPA), the Asian Electronic Sports Federation (AESF) and IOC sponsor Alibaba to include esports as a demonstration discipline at the Jakarta-Palembang Asian Games, the second-largest international sporting event after the Olympic Games.³⁶ Finally, with the joint efforts of the Hong Kong-based Asian Electronic Sports Federation (AESF), the OCA, Tencent and Alisport, esports joined the 2023 Hangzhou Asian Games as a medal sport under the 'intellectual titles' event category, with 476 athletes from 30 nations competing in multiplayer online battle arena (MOBA), battle royale, fighting and sports games.³⁷

In addition to these new developments, virtual sports competitions, which require physical activity and exertion, have started to gain traction in recent years. The Digital Swiss 5, jointly organised by Cycling Unlimited AG/Tour de Suisse, professional cycling organisation Velon and indoor training software developer ROUVY in April 2020, was one of the first major events of this kind. The tournament was created to replace the Tour de Suisse, cancelled due to the Covid-19 pandemic. A total of 57 Union Cycliste Internationale (UCI) WorldTour professional riders competed on five virtual circuits from home on their own bikes, connected to ROUVY's cycling training platform, and the races were broadcast live on TV and online, showing the cyclists' 3D avatars on the virtual tracks as well as their live images captured on home cameras.³⁸ Other sporting governing bodies and event organisers soon adopted this hybrid form of sports competition. For example, in August 2020 UK-based triathlon race organiser Super League Triathlon (SLT) organised the SLT Arena Games in Rotterdam. The event featured 20 professional triathletes competing in three short races following a hybrid Triple Mix format: 200m swimming in an Olympic-sized pool, 4km of cycling on static bike trainers and 1km of running on self-powered treadmills. The three disciplines were alternated after each race, and the cycling and running legs used the Zwift online platform.³⁹

Inspired by the successful esports events at the AIGs and Asian Games, and the newly emerging virtual cycling and triathlon tournaments, the International Olympic Committee (IOC) began to review the possibility of adding esports to the Olympic

Games. In 2017, the IOC concluded at the 6th Olympic Summit that ‘competitive “esports” could be considered as a sporting activity and the players involved prepare and train with an intensity which may be comparable to athletes in traditional sports.’⁴⁰ In 2018, with support from the IOC, Intel hosted a gaming event before the PyeongChang Winter Games in South Korea, featuring the Intel Extreme Masters PyeongChang StarCraft II tournament and an exhibition of *Steep Road to the Olympics*, an IOC-licensed game which features 12 official Olympic winter sports events.⁴¹ It is worth noting that the PyeongChang Games also marked the first Olympics to be livestreamed in VR. Broadcasting was jointly delivered by NBC and Intel through the NBC Sports VR app, utilising 4K camera systems and specially designed optic technologies to present over 50 hours of live virtual reality coverage of 30 events in 360/180-degree stereoscopic 3D.⁴²

Subsequently, the 8th Olympic Summit in 2019 reached agreement that the IOC should facilitate the integration of sports simulations into the Olympic Movement and International Federations (IFs) should ‘consider how electronic and virtual forms of their sport could be governed, and explore opportunities with games publishers.’⁴³ The goal was to use sports games and virtual sports to introduce traditional sports to young people and get them engaged with the Olympic Movement. As IOC President Thomas Bach explained in 2021: ‘Our main motivation is to look for ways how we can convince the people playing these games to do the real thing.’⁴⁴

In summer 2021, the IOC took a substantial step forward by launching its first official esports event, the Olympic Virtual Series (OVS). The event featured five sports: baseball, auto racing, cycling, rowing and sailing.⁴⁵ The IOC hoped to use the OVS to facilitate the development of both physical and non-physical virtual forms of sports, reach out to new audiences, encourage sports participation and spread Olympic values among young people.⁴⁶ It was regarded as a landmark move for both the Olympic movement and esports.

Subsequently, in March 2023 the IOC collaborated with international sporting federations and game publishers to launch the inaugural Olympic Esports Series. The event featured both physical virtual sports and sports video games, covering ten sports disciplines. After the online qualifying rounds, a total of 131 players and athletes gathered in Singapore to compete at the live finals – the Olympic Esports Week – held between 22 and 25 June 2023. The games for competition were selected by the international sports governing bodies. Archery, baseball, chess, sailing, tennis and shooting events were based on traditional gamepad-controlled sports titles as well as mobile and online games, while the other four disciplines used motion-based virtual sports games. The International DanceSport Federation’s Dance competition featured Ubisoft’s *Just Dance 2023 Edition* for Nintendo Switch. In the UCI’s cycling event, 16 cyclists competed in a series of races using the Zwift cycling platform. In the motorsport event regulated by the FIA, players raced on Polyphony Digital’s racing simulation game *Gran Turismo Sport* (2017).⁴⁷

While the AIGs, the Asian Games and the OVS featured esports events on traditional gamepad-controlled video games and physical virtual sports games displayed on screens, the Olympic Esports Series, for the first time, incorporated VR games into an official IOC event. In the taekwondo tournament, regulated by the World Taekwondo Federation, 16 taekwondo athletes, including former Olympic gold medallists, were invited to compete in one-on-one contests using *Virtual Taekwondo*, a VR and motion tracking technology-based virtual sports game devised by World Taekwondo in conjunction with Singapore-based VR

game company Refract Technologies. The game employed motion controllers held in contestants' hands and sensors attached to their legs to capture their physical movements, which were then simulated and replicated in 3D animations. Contestants wore VR headsets and engaged in non-contact combat by kicking into the air, while their in-game avatars' actions were displayed on a large screen. In line with real taekwondo competition, a referee presided over the matches (see Figure 6).

The game offered taekwondo athletes and enthusiasts a unique way to train and compete, and its non-contact nature made it much less intense than real one-on-one contests: players no longer needed to worry about injuries. Third-place finisher Wu Jingyu, a gold medallist at the 2008 and 2012 Olympic Games, summarised the strengths and limitations of the game from an athlete's perspective:

The advent of Virtual Taekwondo has allowed a lot of taekwondo athletes to come to competition, or come back to it. That includes those like me who are retired athletes, or those who have just found taekwondo... I immerse myself fully into enjoying it. I don't have to worry about my age, or health, or injuries... You don't feel the actual touch and feeling of the bodies. In Virtual Taekwondo, it's just the kicks; it actually feels a bit weird. But I think it's fun... Compared with regular training, it's very different. In the virtual game, the speed and accuracy are important, but with the virtual reality headset on, you can't really see clearly, so you have to go off of feel.⁴⁸

In addition to the ten trophy events, exhibition matches were held during the Olympic Esports Week, featuring gamepad-controlled *NBA 2K23*, *Rocket League* and *Street Fighter 6*. There was also a duathlon event in which participants completed the cycling and running legs on static cycling trainers and treadmills, using the Zwift platform, as



Figure 6. Olympic Esports Week, Singapore, 2023 – taekwondo: Wu Jingyu and Nur Tartar.
Source: © 2023/Comité International Olympique (CIO)/NG, Lionel.

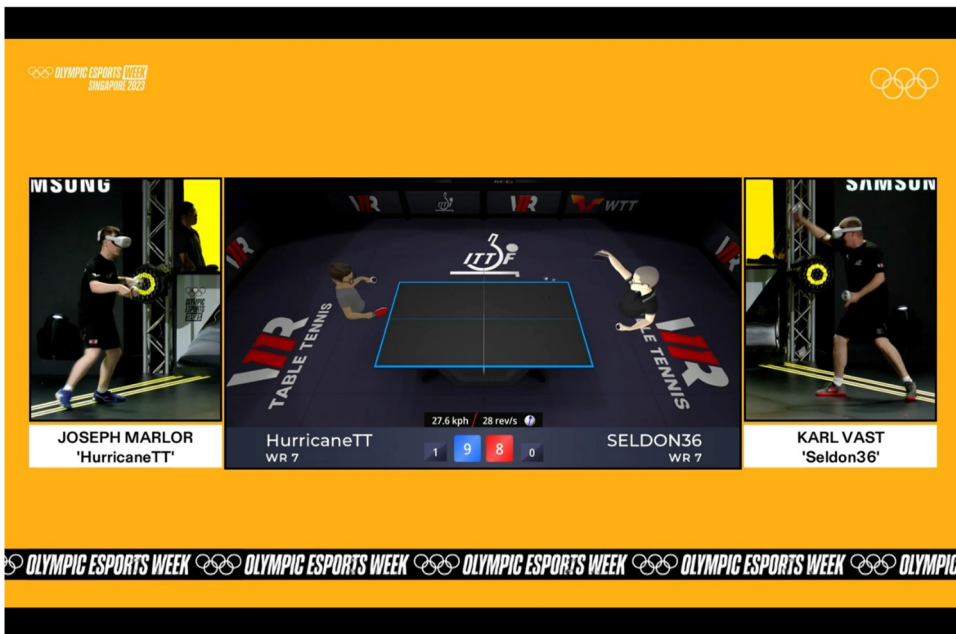


Figure 7. The Table Tennis Exhibition Match at the Olympic Esports Week: Joseph 'HurricaneTT' Marlor and Karl 'Seldon36' Vast.

Source: Courtesy of olympics.com.

well as one-on-one contests on Eleven VR's motion-controlled *Virtual Table Tennis*.⁴⁹ The latter follows the same rules as real-world table tennis, except for the absence of a physical table, ball and paddles. Players wear VR headsets and use motion controllers to engage in virtual matches on *Eleven Table Tennis*, developed by Texas-based For Fun Labs. The game is much less physically and technically demanding than the real sport, thus lowering the threshold for participation and enabling competition between players of different gender and age. This was demonstrated by the first round of the exhibition match, which pitted a 17-year-old nicknamed 'HurricaneTT' against a 50-year-old known as 'Seldon36', with the latter winning 3-2 (see Figure 7).⁵⁰ The VR table tennis game not only offers a refreshing in-person competition experience, it also enables players to participate in online matches against opponents of varying skill levels, thereby enhancing gameplay with increased community engagement, challenge and fun.

Challenges Ahead

The above-mentioned VR games and esports events demonstrate the great potential of VR sports, yet they face several obstacles and challenges. First, the VR gaming industry is still in its early stages. Many of the major game publishers, such as EA, Epic Games, Konami, Nintendo, Ubisoft, Sega and Tencent, remain hesitant to invest in VR gaming because the current VR user base and market size, estimated at 46 million active headsets and \$3.2 billion of revenue respectively by 2024, is only a small fraction of that of traditional consoles, PC and mobile gaming.⁵¹ Since it is less profitable for developers to produce VR games, from the start of the revival in 2013

the overwhelming majority of VR games have been developed and published by small video game developers and independent game studios, with only a handful of AAA titles available, such as Capcom's *Resident Evil VII: Biohazard* (2017) and Valve's *Half-Life: Alyx* (2020). To date, no VR title has been able to match the sales figures of popular PC, console and mobile games, which typically gross billions in revenue. Without support from major sports game publishers like EA and 2K, VR sports games may struggle to reach mainstream audiences and fully realise their potential.

Second, most VR games, particularly those running on battery-powered stand-alone headsets, feature simpler graphics to enable rendering in stereoscopic 3D views (displaying distinct views to each eye, each rendered with slight differences to create binocular disparity) at high resolution and fast refresh rates. In contrast, console and PC games displayed on a single screen require less rendering and processing power, allowing more sophisticated and high-fidelity graphics. This technical limitation may be addressed in the near future with advances in mobile and PC hardware; for the current generation, VR sports games are generally less visually appealing than non-VR titles.

Third, many sports games rely on traditional gameplay mechanics that are not well-suited to VR. For instance, the *FIFA*, *Madden NFL*, *NHL*, *NBA 2K* and *PGA Tour* franchises all adopt a third-person perspective, simulating live broadcasts, incorporating various elements such as tactics, strategies and team management, and granting gamers full control over on-screen players. Translating these features into first-person perspective VR sports games would present significant challenges.

Fourth, the human visual system employs a reflex eye movement known as the vestibulo-ocular reflex (VOR), moving the eyes in the opposite direction to which the head moves. This stabilises the view falling onto the retina, regardless of head movements, as the eyes continuously adjust their position to focus on a particular point. However, current-generation HMDs and VR games adjust in-game camera views based on users' head and body movements. With the absence of the VOR, large or sudden movements during gaming can lead to jarring camera shifts and disorienting visual wobbles, especially noticeable in sports and fitness games that require physical agility, speed, strength and coordination. The rapid and constantly changing views can affect players' visual focus and lead to discomfort and motion sickness.

Fifth and foremost, VR HMDs induce eye strain as users consistently maintain a close and fixed viewing distance (just a few centimetres) in an enclosed environment.⁵² This leads to the crystalline lens staying contracted for extended periods, causing eye fatigue. Additionally, the fixed viewing distance can cause vergence-accommodation conflict (VAC), a visual phenomenon that occurs when the human brain receives mismatching information between the vergence and accommodation of the eyes. While 3D images offer a great sense of depth, the actual distance between the eyes and the screen remains unchanged. This conflict may lead to visual discomfort, dizziness and headaches.⁵³ This limitation is challenging to overcome, because current screen-based display technology doesn't fully align with how the human visual system and brain naturally perceive the world.

Conclusion

This article provides an overview of the development of VR HMDs and VR sports games from the 1990s to the early 2020s. It highlights the influence of new

technologies on game design and innovation across different periods, while emphasising the two-way interaction between video games and real sport. Motion-controlled VR sports games have been changing the way players interact with sports simulations and with each other. These new breeds of sports video games offer a higher level of immersion, new forms of gameplay and real physical engagement that blur the lines between the virtual and real sport. They create new options for people to participate in sports and fitness activities and competitions from home, which is especially beneficial for those who live in urban centres and may have limited access to sports facilities. These games also offer people the opportunity to try out sports that are inaccessible to the majority of the population in real life, such as auto racing, sailing, kayaking, golfing, rock climbing, deep diving, skiing and skydiving.

Additionally, the rapidly developing esports scene has opened new fronts for sports video games in general and VR sports games in particular. Sports governing bodies and event organisers have begun to incorporate VR sports games into international sporting events, paving the way for a new direction in the future development of both sports and video games. This integration not only enhances the entertainment, fitness, education, economic and social values of such events but also serves to bridge the gap between traditional athleticism and the digital realm. It allows athletes, gamers and spectators alike to engage in sport, whether physically or virtually, in real sports venues or other locations via online platforms. To sum up, as computer and information technology advances, VR sports video games are increasingly opening up innovative avenues for entertainment, physical exercise and sporting competition.

Through this introductory exploration, the author aims to raise awareness of the rapidly growing video gaming industry and underscores the necessity for further research into the impact of VR games on the global sports landscape. Limited by its scope and objective, this article focuses on illustrating the historical processes of the rise of VR games and their integration with sports. However, it does not offer a comprehensive analysis of VR sports games' impact on the gaming industry landscape nor provide an in-depth discussion of the influence of VR games on sports participation, consumption and competition. Building on the key findings presented in this article, future research could delve into how stakeholders in the VR sports game sector, including game companies, sports participants, athletes, gamers, spectators and fan communities, sports governing bodies, esports organisations, event organisers and the media, interact and mutually influence each other.

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