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Applications and Challenges for Wearable VR Devices

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Abstract. To meet the growing demands for wearable devices, Virtual Reality (VR) headsets have been developed to deliver immersive and interactive experiences within simulated environments. These devices serve a wide range of purposes, from entertainment to the simulation of real-life scenarios. This paper begins by introducing foundational concepts of VR, and Extended Reality (XR). Then it discusses the applications of wearable VR devices across multiple domains, including healthcare, education and training, engineering and design, entertainment, real estate, automotive industry, and military training. Following this, the paper delves into the technical and practical challenges associated with current VR systems. These include software limitations, hardware performance constraints, ergonomic design, optical and visual quality, user interaction and usability, content creation, accessibility, networking infrastructure, privacy and data security, and consumer perception. Case studies on user experiences are presented to illustrate these issues, followed by proposed solutions to address them. In the end, the paper concludes on the future prospects of wearable VR technology, highlighting its potential to enhance daily life through improved accessibility, comfort, and usability, and to become more seamlessly integrated into everyday activities.

Keywords: Wearable devices, Virtual Reality (VR), applications of VR devices, challenges of designing, software issue of VR

1. Introduction

Due to the requirements of monitoring health metrics, enhancing fitness routines, improving safety and convenience in certain situations through hands-free interaction, etc., wearable devices have attracted people's attention in recent years. A wearable device is an electronic device designed to be worn on a person's body that has processing or communication capabilities and features that allow for other usages like monitoring health or making extended realities.

Some examples of wearable devices in our daily lives are smart watches like Fitbit or the Apple Watch. These devices help track your health and body activity while you are moving, sitting or exercising. Other examples are Virtual Reality (VR) headsets like Oculus or Meta Quest. These devices create a space of virtual reality that completely immerses the user in a digital world where they can play games, watch videos and socialize with the community of the VR world [1]. A VR headset includes headphones like AirPods or headsets which aid the user in listening to audio

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without interruptions from bystanders, while keeping in-game audio to themselves without disturbing their surroundings [2].

VR is a simulated three-dimensional environment that immerses users in virtual surroundings that they can interact and explore with. The surroundings are completely computer generated, and users can explore it via their senses like touch and sight. It often requires a headset and handheld devices. Another similar concept is Augmented Reality (AR). AR is the real-time usage of information in the form of text, graphics, audio and other virtual objects that are integrated with real-life objects [3]. As some of objects are still computer generated, it uses the layout of the real-life surroundings to generate the virtual objects. For example, the Apple Vision Pro uses the surroundings to generate screens for users to interact with. In addition to VR and AR, Extended Reality (XR) is a general term for AR, VR and Mixed Reality (MR) and everything in between [2], meaning that everything that is computer generated or has some parts of computer generation is categorized as XR as it is a form of extended reality that is not part of reality.

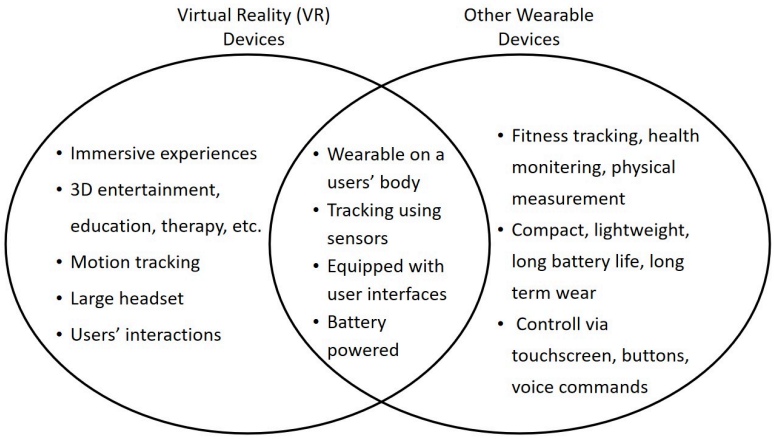


Figure 1. Different functions and characteristics between VR devices and other wearable devices

Figure 1 shows differences between VR devices and other wearable devices. While VR devices are primarily used for immersive experiences such as gaming and virtual reality environments, they can also be used for other purposes, for example, education and therapy. As shown in Figure 1, other wearable devices are designed for convenience, fitness, tracking and more (ex: apple watch) [4]. VR devices are normally larger compared to lighter and smaller wearable devices such as watches or glasses. On the other hand, there exist some common functions for both VR devices and other wearable devices, such as tracking human movement using sensors, interacting with human using equipped interfaces, etc.

2. Applications for wearable VR devices

VR devices can be widely applied in healthcare, education and training, engineering and design, entertainment, real estate, automotive industry, and military training. The details of these applications are given as follows:

DOI: 10.54254/2755-2721/2025.GL24528

2.1. Healthcare

2.1.1. Doctor experience

Wearable VR devices contribute tremendously to the training of doctors. For example, they provide procedure training for massive operations like surgery, where doctors train with virtual patients that mimic real-life surgery. This process is not only cost-effective compared to traditional training methods that use physical models and cadavers but also allows for quick yet efficient training that promotes more repetition and mastery. As a result, doctors can practice without the limitations of cadaver availability or the risk of injuring live patients [5]. Doctors can also save money on education as they do not have to pay for expensive flights to see instructors. As they can interact through VR, the instructors can guide the doctor via a simulated demonstration. VR devices can also provide realistic patient interactions, allowing medical professionals to develop soft skills like communication, empathy, and bedside manners. Trainees can also practice delivering bad news or dealing with complex patients in a controlled setting [6].

2.1.2. VR therapy

VR devices engage in patients' mental health by offering therapy sessions where VR can simulate calming influences like videos or distractions that may improve the patient's mind and mental well-being. It can provide a 3-Dimension (3D) nature scene therapy, where the device simulates nature in a calming tone to help deal with extreme anxiety or stress where the patient might need some calming influences. Not only can VR calm patients, but it can also help patients who suffer from anxiety or fears by helping them develop coping mechanisms and gradually overcome their challenges [7]. VR devices are also used to simulate real-life interactions between people, and they can be used to teach social skills to individuals with disorders in simulated environments where they can safely overcome their fears.

2.1.3. Fitness / exercise

VR devices help with exercise, as they create immersive scenery that helps improve engagement and motivation [7]. They can turn exercise into a game where users complete quests and earn rewards for burning calories. VR devices can also allow users to exercise in various virtual settings, from iconic scenery to fantasy worlds, keeping the experience light, fresh, and exciting while reducing workout monotony. It also allows users to exercise with a friend with a multiplayer platform, which can help motivate people to train harder, lighten up their mood, and improve efficiency and enjoyment in their workouts.

2.2. Education and training

2.2.1. Education / teaching

VR devices are better at capturing students' attention than traditional teaching methods by immersing them in virtual environments, making learning more engaging. Virtual environments can also increase student interest in learning and help students retain more information than reading. Studies have shown that students are more likely to remember information learned through active participation rather than passive reading or listening [1]. Teachers can turn their attention quickly to students who are struggling more than others, as the VR can deploy an AI teacher that can do one-

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on-one essential learning anytime the students need, allowing the teacher to help those who need extra explanation and demonstration.

2.2.2. Employee training

VR devices are an important part of employee training as they offer a cost-effective way to provide equal employee training with no bias. The initial investment in VR equipment may seem excessive, but it significantly reduces the costs associated with traditional training methods, such as travel, accommodation, and physical training materials [8]. Realistic simulations and engaging, immersive exercises in training allow employees to improve skills such as retention and understanding the material without any risk of upsetting real customers [7]. VR simulation allows employees to practice memory through repetition and hands-on practices. It also benefits employees who struggle to find time by offering remote learning, while presenting a variety of diverse scenarios that better equip them to handle potential incidents [9].

2.3. Engineering and design

VR devices save engineers and companies money and time to build expensive, real-life 3D models. The VR devices enable users to fully immerse themselves in the prototype model, allowing them to make active adjustments that are both more efficient and precise. VR also allows for remote collaboration by allowing the team to work on a project in a shared virtual environment, which can improve communication and decision-making [9].

2.4. Entertainment

2.4.1. Gaming

VR devices provide entertainment in many ways, such as immersive gameplay, enhanced storytelling, and social VR gaming. VR is used to play multiple immersive games, for example, Beat Saber and Fishing Simulator. Being in a virtual world is quite an experience as users genuinely feel like they are fishing. Adding in the audio cues makes the experience more immersive – something traditional games cannot match. VR devices also make the gameplay more engaging and physically active, allowing players better hand-eye coordination, motor skills and enhancing a player's spatial awareness in a confined space [10]. This physical activity enhances the gaming experience and energizes and activates the audience. Many VR games also have complex puzzles and challenges that may enhance cognitive skills such as problem-solving and critical thinking while improving quick decisions and reactions under pressure. VR games can also help users socialize via virtual communities or play multiplayer games with their friends, which builds bonds.

2.4.2. Personal experience

Since acquiring a VR device in 2020, my initial experience was both surreal and exhilarating. It was unlike any other sensation I had previously encountered. While adjusting to the virtual reality environment posed some challenges initially, once I overcame them, the enjoyment I experienced was truly incomparable. The VR games I engaged with varied from relaxing experiences to intricate puzzles. After each session, I found myself physically exerted, often sweating from the movement. One particularly remarkable feature of the VR experience was the striking realism of textures. It genuinely felt as though I were fishing in a lake or boxing against an opponent. While I typically

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played games on a personal computer (PC), the VR experience proved to be far more personal and immersive. In contrast to the traditional PC setup, where I was confined to a screen, VR allowed for a deeper sense of engagement. Moreover, I found that playing online games with friends in VR was far more enjoyable than simply communicating through Discord while playing on a PC.

2.5. Visualization of real estate

VR devices allow architects and clients to view real estate properties, giving them a sense of space and layout. VR also enables clients to explore a variety of furniture options before making a purchase, allowing them to assess how each piece contributes to the overall design of their home. This not only helps clients avoid spending money on furniture that may not suit their space but also saves time by enabling them to explore multiple design options and virtual homes within a few hours [11].

2.6. Automotive industry

2.6.1. Visualization / safety

VR devices allow designers to visualize car models and adjust them as necessary without many physical prototypes. They also allow managers to fine-tune the assembly lines and optimize workflow. VR devices can also help designers visualize crashes via crash simulations. Crash simulations allow workers to analyze the impact on the structure and safety of the occupants, reducing the need for any physical tests [12]. All of this allows for more prototyping to create the best car that suits consumers while protecting drivers and passengers from accidents.

2.6.2. Client advantage

VR devices allow the clients to visualize cars in different environments and how the car operates under different types of road conditions via simulations. The simulated view of interior and exterior of the car can also help with their decision-making [12]. This also saves them a lot of time in real-life test drive, as they can see all the different variants immediately.

2.7. Military training

VR devices help soldiers get ready for the battlefield as they allow the soldiers to engage in realistic combat scenes while practicing team tactics, strategies, and decision-making in a controlled environment. VR devices can replicate different battlefields ranging from urban cities to deserts. VR devices can also help simulate an upcoming mission, allowing individuals to rehearse it in a virtual setting closely mirroring the conditions of the battlefield [13]. All of this can be completed under the watchful supervision of a commander or drill sergeant, who can correct the team's flaws before they go on the mission.

3. Design challenges for wearable VR devices

Although wearable VR devices provide several benefits, there exist many challenges for designing a VR device, including

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3.1. Software issues

Older models cannot be booted with new software, and system changes do not allow older models to transition seamlessly into a new phase, for example, a software bug that claims your product is corrupt and in need of replacement. This creates a false sense of worry instilled in the user. However, for a complex user interface (UI) that doesn't allow users to easily transition accounts between devices, the user must go through complicated processes that are not presented clearly in the UI and account settings. Also, the META app UI is not properly loading because of differences in Apple vs Android software. In addition, bugs in the system don't allow for seamless connection between mobile devices and the VR headset.

• Possible Solution: Designing an improved UI that facilitates smoother transitions, clearly highlights key issues, and offers actionable solutions—eliminating the need for users to guess or search for help online. The new design should display an error message with a link to the help center or support site, providing guidance and reassurance instead of leaving users worried that their VR device is broken. In addition, companies should improve their systems to allow for a better transition from old to new devices or accounts that do not just randomly malfunction without a legitimate explanation.

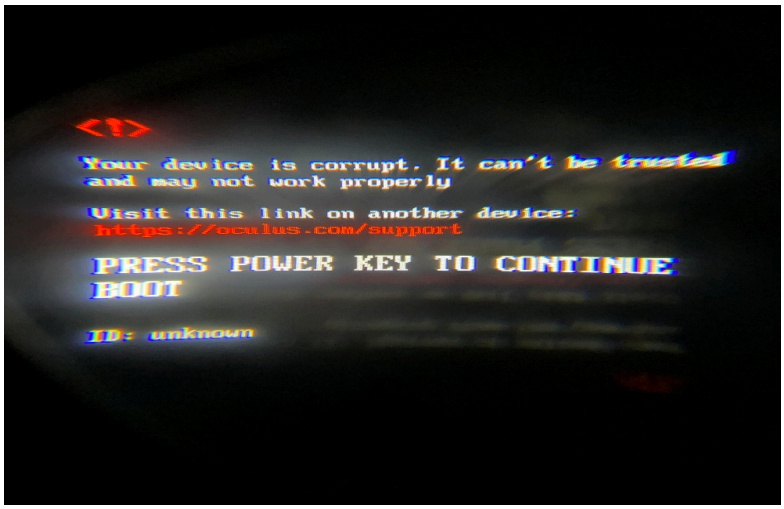


Figure 2: Malfunction of the VR Meta Quest

Figure 2 shows what happens when the author's VR Meta Quest files malfunction during setup or login. It shows that the device is supposedly corrupted even though the user has done nothing. Along with confusing instructions on how to solve this issue, this adds to the growing paranoia that the user has just lost a 300+ USD video game device. Meta also has no detailed procedure to fix these issues on its support page, so the user must go to Reddit or other sources to try fixing the VR.

3.2. Hardware and performance

Computer Chips and their processing power, as well as latency and display resolutions, are big challenges that worsen the experience a customer might get from VR. Battery life is exclusively important as it is the top area for improvement. Even with the fastest performance, a device with poor batter life is unlikely to please users [9].

• Possible Solution: Although there is no immediate solution, ongoing research and innovation continue to drive progress in this space, leading to breakthroughs in longer-lasting batteries and

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more powerful computer chips.

3.3. Ergonomics

Weight distribution ensures that it is comfortable to wear. As users will be wearing a VR device on their heads for more than 1 hour, the discomfort will only generate complaints and hatred towards the product.

• Possible Solution: To use more comfortable materials like foam, sponge, or air pillow to allow for less stress and discomfort for the user, while allowing the device to keep its pricing without much additional cost. To combat eye strain, the design must integrate better optics and Interpupillary Distance (IPD) distances [14].

3.4. Optics and visual quality

Lens distortion, low color accuracy, and suboptimal brightness and contrast are major problems that impact on user experience. To ensure a comfortable user experience, VR headsets need to be more compact and have lightweight, near-eye displays. However, most VR headsets are bulky, in which most of the internal space is unused. The excessive volume creates a distance between the display panel and viewing optics, which contributes to stress on eyes over prolonged use [15].

• Possible Solution: A potential solution could be to reposition the display panel closer to users' eyes and install imaging optics in between to reduce eye strain. Although these solutions may be inadequate with the limitations of angular resolutions, advancements in display panel resolution and advanced fabrication will gradually resolve this issue.

3.5. Interaction and usability

Most VR devices are not well suited for smaller kids or adults with larger heads. The interaction between the display and user input is also inadequate; in some cases, systems exhibit latency that impacts usability. Additionally, there is a lack of clear and handy instructions, resulting in a steep learning curve, which frustrates users and hinders engagement.

• Possible Solution: Further research is needed for motion tracking, controller design and haptic feedback for a better ergonomic input and a realistic touch sensation, as well as enhanced accessibility ensuring that people of all ages and types can use it safely and effectively.

3.6. Software and content

In some cases, VR device software is laggy and not user-friendly. VR gaming interface can be difficult to navigate, with unclear access to software settings and updates. VR also lacks cross-platform compatibility that allows VR users interact with PC gamers. In the long run, this will result in a more and more isolating experience for VR users.

• Possible Solutions: Cross platform compatibility, content development and updates and maintenance allow for better engagement and better VR content to make VR game exciting and fun. Besides, a better user interface that clearly displays important settings and features would be quite helpful. Furthermore, implementing a search bar within the settings page would provide users with more efficient access to desired configurations.

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3.7. Health and safety

Heavy use of VR can lead to health and safety concerns, including motion sickness, excessive exposure to blue light which may cause severe discomfort. Physical safety is another concern: users may be unaware of their surroundings. This can cause injuries such as bumping into furniture, hitting limbs against objects or tripping [16].

• Possible Solutions: Deploying a better warning system to alert users of potential dangers surrounding them might be effective preventative control. An upgraded programming system is needed to create reasonable distance between actual objects and the protective barriers. The upgraded system can also be used to provide better resolution, smooth motions, and reduce visual delays. Companies can create blue light filters to fit onto the lenses to combat the blue light damage.

3.8. Cost and accessibility

VR is not the most expensive thing a user will ever buy. However, the 600 USD is excessive for a device many people use occasionally. The cost limits many technology enthusiasts from engaging with VR platform they are passionate about [16].

• Possible Solutions: Creating more cost-efficient materials or lowering the other cost of production may lead to high-quality yet less expensive products.

3.9. Networking and social interaction:

VR devices experience network connection issues, which makes playing VR games frustrating and stressful. Additionally, poor user interface design hinders seamless communication, making it challenging for users to quickly interact with friends in VR environment.

• Possible Solutions: VR experiences require substantial bandwidth and system resources to operate smoothly and give users delay free experience [16]. In addition, in support of multiplayer gaming and in-game communication can promote richer social interaction and more immersive gameplay.

3.10. Privacy and security

Insufficient data protection controls with VR devices and systems expose individuals to significant privacy and security risks, including unauthorized access, track and use of personal information. Users may face consequences such as identity theft or reputational harm [16].

• Possible Solutions: Implement strong data protection measures, for example, end-to-end encryption to minimize the risk of unauthorized data access and tracking. Strict access provisioning and de-provisioning process is required to apply to servers and other IT infrastructure supporting VR.

4. Conclusion

In conclusion, VR technology has tremendous potential to enhance various aspects of daily life, including education, work and entertainment. It creates immersive experiences that offer both practical and recreational value. However, its current limitations, such as discomfort from excessive use, motion sickness and user interface challenges continue to slow down its broader adoption. As technology advances, improvements in ergonomics, optimized software, and enhanced user interface

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development will uplift VR technology to become more accessible, comfortable, and more integrated into everyday life.

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