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Research on Visual Fatigue and Discomfort of Amblyopic People in VR Environment

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Abstract: The advent of virtual reality (VR) technology has marked a significant leap in immersive experiences, offering unprecedented opportunities in various sectors such as gaming, education, healthcare, and professional training. However, the current VR systems face notable limitations, particularly in terms of visual resolution and field of view, which are inferior to human visual capabilities. This results in reduced visual acuity and clarity, creating a barrier for users with visual impairments or those who require corrective lenses. This overview delves into the visual limitations of VR devices, examining the impact of resolution and field of view on user experience. It discusses the relationship between resolution and image clarity, highlighting the need for advancements in display technology to match or surpass human visual acuity. While VR holds immense potential, it is imperative to address its current limitations and focus on research and development aimed at making VR technology more accessible and comfortable for a wider range of users. The future of VR lies in its ability to integrate multiple sensory modalities, thereby creating a truly inclusive and immersive digital interaction era.

Keywords: Virtual Reality (VR), Visual Impairments, Multisensory Feedback, Resolution and Field of View, Inclusivity and Accessibility

1. Introduction

Virtual reality goggles (VR glasses) represent a significant advancement in immersive technology, offering users an experience that surpasses traditional media. By creating a fully interactive three-dimensional environment, VR goggles transport users into a virtual world where they can explore, interact and engage with digital content in ways previously unimaginable. These devices typically consist of a head-worn screen and integrated sensors that track head movements, providing a fluid and responsive experience.[1]

VR glasses are equipped with high-resolution screens and advanced optics, which provide realistic images that enhance the sense of presence and immersion. VR glasses are used in a variety of fields, including gaming, education, healthcare and professional training, making them a versatile tool for both entertainment and practical purposes. In gaming, VR glasses offer a captivating and realistic experience, while in education they create interactive learning environments that improve understanding and retention. In the field of healthcare, VR glasses are employed for therapeutic purposes and surgical training, thereby providing a secure and regulated setting for exercise. As VR technology continues to advance, the potential for VR glasses to transform the manner in which

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humans interact with digital content and with each other becomes increasingly evident, thereby inaugurating a new era of digital interaction and immersion.

Virtual reality (VR) should be accessible to all, including those with physical or cognitive disabilities and the visually impaired. Sectors such as education, training and entertainment can benefit greatly from VR. However, the majority of head-mounted portable displays have a significant drawback: their resolution is significantly lower than that of the human eye and their field of vision is limited [2]. The consequence of this is a reduction in visual acuity, comparable to that observed in individuals with mild visual impairment, and the generation of blurred or pixelated images, which detract from the VR experience. For individuals with visual impairments, the wearing of glasses or contact lenses in VR can be uncomfortable or impractical.

2. Visual limitations of VR devices

2.1. Impact of VR resolution and field of view angle

The resolution of VR glasses is usually lower than that of the human eye, and the head-mounted display has a smaller field of view, so the image is not clear enough, which can reduce visual acuity. In particular, people with corrected vision, i.e., those who wear contact lenses or glasses, tend to experience a slight decrease in visual acuity when using head-mounted displays in virtual reality (VR), similar to a visual impairment.

This is because the low resolution of VR displays often means that the images are blurry and pixelated, greatly reducing the quality of the virtual environment (VE). This is particularly problematic for users with visual impairments, as it is often inconvenient or impractical to wear additional glasses on virtual reality displays of contemporary design.

In addition, some people with corrected vision do not tolerate contact lenses, which further complicates the VR experience. Modern high-definition VR glasses increasingly use eye-tracking technology for advanced features such as focus projection and to optimize screen performance by reducing image quality in peripheral vision. However, such eye-tracking systems cannot be adapted to users wearing glasses, which reduces the experience of VR glasses for users wearing glasses [2].

2.2. The relationship between resolution and image clarity

The resolution and field of view of virtual reality glasses are usually inferior to that of the human eye, resulting in unclear images and reduced visual acuity. Individuals with corrected vision experience a further reduction in visual acuity when using a VR head-mounted display (HMD), similar to a mild impairment. People with normal vision also tend to feel that objects are not as clear as they are in the real world when using head-mounted displays (HMDs); the lack of clarity is mainly due to the fact that the field of view of a VR headset is wider than that of a desktop display.

The resolution (PPI) and total number of pixels in a display have no significant effect on the clarity of an object, and a higher resolution in an HMD does not necessarily mean better image quality. Since the field of view of a VR headset is wider than that of a desktop, the overall pixel density is reduced, and although the resolution is higher, the clarity of the image receives an overall reduction. Resolution is not always a way to improve the clarity of VR images. Low resolution can lead to the generation of blurry, pixelated images, which can be especially problematic for people with visual impairments. This also highlights the difficulty of achieving clear images in virtual reality, while factors other than resolution, such as field of view and pixel position, also play an important role in determining the overall quality of the display [3].

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2.3. VR Experience Optimisation

2.3.1. vision correction

Many VR headsets are not designed to accommodate prescription glasses comfortably, making them difficult to use for people with vision impairments. When people wear VR glasses, partially sighted users and most senior users need to wear their own corrective glasses in the physical space between the VR glasses screen and their eyes. This is extremely inconvenient because different glasses have different focal lengths, and the user's focal range is limited by the focal range of the lenses of the corrective glasses, forcing the user to change the position of their glasses or head during use to focus on a particular image [4]. This not only affects the immersive experience, but may also lead to eyestrain, dizziness and other uncomfortable symptoms. In addition, many VR devices fail to adequately consider the needs of users wearing glasses, and the wearing experience of the device becomes urgent or uncomfortable as a result. Individuals with impaired vision may require customised VR glasses and Internet of Things (IoT) connectivity to enhance their virtual reality experience [5]. This suggests that VR glasses usually fail to meet the needs of most part of the partially sighted as well as visually impaired groups, and that ordinary VR devices will make these users feel uncomfortable. When using VR glasses, partially sighted and visually impaired users are often unable to enjoy the same immersive experience as normal sighted users because the design of the device fails to adequately take into account their special vision needs. For example, the fixed focal length and small field of view of VR glasses make it difficult for partially sighted users to clearly see details in the virtual environment, and may even produce eye fatigue, dizziness, nausea and other uncomfortable symptoms during use [6]. In addition, the design of many VR devices does not fully consider the needs of users wearing corrective eyewear, making them feel tight and uncomfortable when wearing VR glasses, further exacerbating the inconvenience and discomfort during use. In response to this situation, there is an urgent need to introduce more humane considerations and technological innovations into the design and manufacturing of VR devices, and to provide solutions that are more suitable for partially sighted and visually impaired users, such as VR glasses with adjustable focal lengths, customized lens services and smart glasses solutions. This will not only help enhance the virtual reality experience of partially sighted and visually impaired users, but also promote the popularization and application of VR technology, bringing convenience and fun to more users.

2.3.2. low vision

It is of paramount importance that individuals with low vision have the option of adjusting the visual display screen in a virtual reality setting. The type, size and colour of the display screen of VR glasses are crucial for people with low vision [7]. In order to facilitate the experience of virtual reality for users with partial sight, it is necessary to ensure that colours are more visible, fonts are larger, text types are specialized and graphics are provided. However, conventional settings may result in users not being able to fully experience the fun and convenience of virtual reality. In addition, screen display brightness and blue light issues may lead to further vision loss and even sleep disruption for users. The luminosity of some of the lights is insufficient for optimal visual effect, resulting in a lack of contrast between objects that is not readily discernible by the user. Conversely, the brightness of other lights is excessive, potentially causing ocular irritation and adversely affecting visual performance when observing details over an extended period [8]. This causes visual fatigue and discomfort to the user, which can have an impact on vision.

3. The importance of multisensory feedback in VR

The majority of virtual reality tools are reliant on visual feedback, which restricts the experience and usability for individuals with visual impairments and partial sight. Modern VR headsets often use eye-tracking technology [9], which can be less effective or inaccurate for users wearing glasses. This leads to the VR glasses being unable to identify the needs of highly myopic and visually impaired users and provide timely feedback, which in turn reduces the user experience. The majority of virtual reality devices currently available on the market are designed to provide primarily visual feedback, with minimal consideration for feedback to the other senses [10]. This exclusive reliance on a single sense presents a significant obstacle for individuals with visual impairments in utilizing VR devices. They are unable to fully benefit from the visual feedback, which is essential for experiencing the full immersion of virtual reality. While some devices are beginning to introduce haptic and acoustic feedback, their application and effectiveness remain limited. In order to enhance the inclusivity of virtual reality devices and meet the diverse needs of users, future developments should incorporate feedback systems that integrate multiple senses. For instance, the incorporation of haptic and auditory feedback, as well as the introduction of olfactory and thermal stimuli to supplement visual feedback, could be beneficial [11]. Furthermore, the development of display technologies adapted to partially sighted users, such as high-contrast screens and adjustable focus lenses, will also assist in enhancing their experience [8]. The incorporation of multiple sensory modalities into the design of virtual reality devices will not only facilitate the enhanced experience of partially sighted users, but will also provide a more immersive and realistic experience for all users.

4. Conclusion

Despite the transformative potential of VR, there are significant challenges related to visual limitations that affect the user experience, particularly for those with visual impairments or corrected vision. To optimize the VR experience for individuals with vision impairments, several adjustments are necessary. Comfort and compatibility with prescription glasses are critical, as is the development of VR glasses with adjustable focal lengths and customized lens services. For users with low vision, adjustable display screen settings, larger fonts, specialized text types, and enhanced graphics are essential. However, these adjustments must be made with consideration for the potential negative impacts on vision, such as screen brightness and blue light exposure, which can lead to further vision loss and sleep disruption.

While strides have been made in VR technology, there is a clear need for further research and development to address the current limitation to ensure accessibility and comfort for all users. By focusing on these research directions, the VR community can work towards a future where virtual reality is not only a technological marvel but also an inclusive and accessible tool for enhancing human experience.

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