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Application of Home-Based XR Art Experiences for Emotional Healing in Elderly Individuals with Mobility Issues: Eye-Tracking and Virtual Natural Landscape Design

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Abstract:
With the rapid development of Virtual Reality (VR) and Augmented Reality (AR) technologies, Extended Reality (XR) is increasingly demonstrating its potential in the field of emotional healing. This paper focuses on the application of home-based XR art experiences for emotional healing in elderly individuals with limited mobility. Through immersive interactions and the design of virtual natural landscapes, XR helps alleviate psychological stress and anxiety, enhancing the well-being of elderly users. In addition to analyzing how XR technology, through eye-tracking and multimodal affective computing, combined with personalized and contextual design, provides emotional healing and psychological support for elderly users, this paper proposes several recommendations for future XR system designs. Specifically, it suggests improvements in adaptive interface design, integration of physiological feedback, and the enhancement of virtual social functions to better meet the emotional needs of elderly individuals, ultimately improving their quality of life.

Keywords: Extended Reality (XR), emotional healing, eye-tracking, virtual natural landscapes, elderly

1. Introduction

In recent years, Virtual Reality (VR) and Augmented Reality (AR) technologies have made significant progress, and XR technology has shown potential as a tool for emotional healing [1], especially in helping elderly individuals with mobility issues alleviate loneliness and psychological stress [2]. The reliability and effectiveness of this technology provide a solid foundation for its application in emotional healing. Home-based XR art experiences, through immersive interaction and emotional resonance, can effectively reduce stress and anxiety, enhancing overall well-being. This research aims to explore how home-based XR art experiences achieve emotional healing and analyze the principles of their design in such contexts.

2. Background and Significance

The growing concern of global aging presents significant challenges, particularly for elderly individuals, aged 70 to 85 and above, who often face reduced mobility, making it increasingly difficult for them to travel or engage with the natural environment. This decline in physical activity not only limits their ability to participate in social activities but also exacerbates feelings of loneliness and psychological stress, which can severely diminish their quality of life. For those residing in nursing homes, where physical and environmental constraints further restrict outdoor activities, these challenges become even more pronounced, intensifying the psychological distress experienced by many. At the same time, the elderly possess a wealth of life experiences and wisdom that remain underutilized, yet these assets can be of great value to societal development [3]. Recognizing these challenges and opportunities, this study aims to harness XR technology to provide a platform for emotional healing and psychological support, ultimately helping elderly individuals reintegrate into society and share their unique contributions. The study builds on previous research, which indicates that the elderly have a strong desire for social engagement, particularly in relaxed, dynamic environments where they can interact with others [4]. To address this need, this paper presents a study on the development of MoodLink XR, a prototype system designed to create a vibrant virtual social space tailored to the needs of elderly individuals with mobility impairments. In order to reduce feelings of loneliness and improve emotional well-being, the study explores how immersive XR technology can be applied to foster meaningful social interactions. Through MoodLink XR, elderly users can engage in virtual environments that promote emotional healing, enhancing their quality of life by providing an alternative to real-world socialization and emotional support.

3. Literature Review

In recent years, numerous studies have highlighted the significant effects of virtual reality technology in emotional healing, particularly among the elderly [2]. For example, the application of multimodal computing in emotion recognition has provided theoretical support for the eye-tracking technology used in this study. Research has also shown that natural environments can significantly reduce stress and anxiety [5]. Through AR technology, users can experience virtual natural landscapes, such as forests, beaches, and gardens, in their daily lives. These virtual environments not only provide visual relaxation but also enhance the effect with natural sounds like birdsong and running water [6]. These visual and auditory effects are delivered through XR devices, providing psychological comfort without interfering with normal activities.

Currently, emotion computing technology largely relies on models that recognize basic emotions, but these models are primarily developed based on datasets from Western cultural contexts [2]. This Western-centric approach limits the adaptability of current emotion computing systems, especially when applied to elderly populations in Asia, who may express emotions differently due to cultural influences. Barrett's constructionist theory of emotion posits that emotions are dynamically constructed and shaped by context, individual experience, and cultural background [7]. Therefore, existing emotion computing models face significant limitations when applied to elderly individuals from non-Western cultures, as they do not account for the cultural nuances in emotional expression [8]. Furthermore, while multimodal emotion recognition enhances accuracy, it still encounters challenges in integrating cultural context, making it difficult to provide personalized emotional support for Asian elderly users [6].

4. Research Methods and Technological Implementation

4.1 Analysis of Existing Technologies

XR technology has seen notable advancements in consumer-grade devices in recent years, especially with the increasing use of VR head-mounted displays (HMDs) and eye-tracking technology. However, despite these advancements, there are still several challenges and limitations in the existing technologies, particularly for elderly users.

Eye-Tracking Precision and Field-of-View Accuracy: Current eye-tracking technology in consumer-grade devices can perform basic interaction functions but faces significant precision and calibration issues, particularly for elderly users with declining vision or slower eye movements [8, 9]. Additionally, these systems provide higher accuracy in the central field of view, but peripheral accuracy declines significantly. For example, the HTC Vive Pro Eye's precision is limited to a 20-degree range in the central field [9]. This reduction in precision can lead to operational errors and a diminished user experience, especially for elderly users who require enhanced tracking to accommodate slower eye movements and reduced control.

Data Quality: The quality of data collected by eye-track-

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ing devices, particularly spatial accuracy, is critical for applications involving small eye movements such as fixations and microsaccades. However, the precision of current HMD-based eye trackers in real-world environments often falls short of ideal conditions, affecting the interaction experience [9].

Comfort, Interaction Methods, and User Interface Design: XR devices are typically designed for younger users, and their weight, size, and complexity may not be suitable for elderly users. Heavier headsets can cause neck and shoulder pain during extended use, particularly in elderly individuals with weaker muscles [10]. Additionally, traditional handheld controllers may not be ideal for users with limited mobility, such as those using wheelchairs or suffering from arthritis. Introducing natural interaction methods based on eye-tracking and head movements can simplify operation, reducing reliance on manual inputs. Furthermore, current VR interfaces often overlook the cognitive needs of elderly users, leading to challenges with high interface complexity, low icon usability, and low text readability [11]. Improved ergonomic and interface designs are necessary to enhance usability and satisfaction for elderly users.

Adaptation to Virtual Environments, Motion Sickness, and Physiological Differences: VR technology offers immersive experiences, but for elderly users, rapid movements or complex visual effects can trigger motion sickness or visual fatigue [12]. This is particularly problematic for users sensitive to visual and spatial perception [12]. Gender and physiological factors, such as blood pressure and heart rate, also impact motion sickness, with female users being more susceptible [13]. To minimize these issues, system designs should include motion sickness prevention techniques, such as reducing movement speed, stabilizing visual content, and ensuring gradual transitions between scenes. Additionally, virtual environments should avoid high-contrast, flickering, or rapidly changing visual elements to ensure a stable, comfortable experience for elderly users.

Latency Issues: Latency is a critical issue affecting real-time interactive experiences. The current latency range for HMD-based eye trackers is between 45 milliseconds and 81 milliseconds, which, while suitable for non-real-time applications, may pose challenges for highly interactive applications [14]. High latency can disrupt user immersion, cause frustration, and even exacerbate motion sickness, particularly for elderly users who may be more sensitive to visual delays.

4.2 Prospects for Future Technological Development

To better address the limitations of existing technologies, future XR systems need to improve across multiple dimensions, particularly in emotion computing, multimodal interaction, personalized adaptive design, and the integration of assistive devices.

Multimodal Emotion Computing Integration: Multimodal emotion computing integrates various data sources, such as voice, facial expressions, and body posture, to more accurately capture users' emotional states. This approach allows systems to better understand emotional changes and adjust virtual environments dynamically, enhancing the emotional healing experience. For instance, when users are feeling low, the system can switch to calming landscapes or soothing music to help alleviate emotional pressure and anxiety.

This emotion computing framework is more flexible than traditional static emotion classification models. Static models typically rely on preset emotional categories and ignore the complex variations of emotions across different contexts and cultural backgrounds. In contrast, multimodal emotion computing integrates sensory inputs, cultural contexts, and situational factors to dynamically construct users' emotional states in specific contexts, offering more personalized and culturally adaptive emotional predictions [7]. Therefore, multimodal emotion computing enhances the accuracy of emotion recognition and provides the technological foundation for dynamic, flexible emotional healing.

Personalized Adaptation and Data-Driven Design: Future XR systems can consider the personalized needs of each elderly user. By collecting and analyzing user behavior, preferences, and physiological data (such as eye movements and operation speed), systems can automatically adjust the complexity of virtual scenes and interaction methods. For example, for users with more flexible eye control, the system can introduce more complex interaction designs, while for users with weaker vision, the system can simplify the interface and enlarge key elements. The application of machine learning and artificial intelligence can help systems iteratively improve based on user data, providing more personalized experiences that cater to the diverse needs of elderly populations [15].

Integration of Assistive Devices and Wearable Technology: For elderly users with mobility issues, future XR systems can integrate more assistive devices, such as control devices based on muscle signals or simple gestures. These devices can reduce reliance on traditional controllers or eye-tracking operations, offering more natural interaction methods. Future XR systems can also integrate wearable technology, such as smart gloves or electromyographic sensors, allowing users to control virtual environments through simple hand or body movements, helping elderly users with movement impairments participate in virtual experiences more effectively [16]. Combining eye-tracking with other sensors (such as head movement data) is a future research direction that can improve the accuracy and interaction experience of eye-tracking data reconstruction.

Improved Data Processing and Accuracy: Recent advancements in machine learning and sensor fusion technologies have been applied to enhance the precision of eye-tracking systems. These developments aim to better recognize various types of eye movements, and future improvements in artificial intelligence are expected to further optimize the accuracy of eye-tracking in XR systems.

Physiological Feedback Integration: Future XR systems need to integrate physiological data such as heart rate and blood pressure to better meet the needs of elderly users. Studies have shown that scary virtual environments significantly impact users' physiological feedback (such as heart rate and blood pressure) [13].

Personalized Virtual Environment Design: Depending on the virtual environment, users' physiological reactions and motion sickness experiences may vary significantly [13]. For instance, pleasant scenes significantly reduce the occurrence of motion sickness, while frightening scenes amplify negative reactions.

Improvement of Personalized Interaction Design: To enhance the acceptability of XR technology, future system designs should fully consider the cognitive, perceptual, and motor changes of elderly users, avoiding overly complex interfaces and reducing the fear of technology through more intuitive interaction methods [11].

4.3 System Design and Implementation

The system design of MoodLink XR integrates eye-tracking technology and virtual natural landscapes, focusing on the physiological and psychological needs of elderly users. The following section describes the specific aspects of system design and interaction implementation:

Interaction Based on Eye-Tracking and Head Movements: To reduce reliance on manual operations, the system is designed with an interaction scheme based on eye-tracking and head movements. Users can control their perspective by moving their eyes and activate an automatic path-following function by gazing in a specific direction. When users continuously gaze in one direction in a virtual scene, the system automatically advances along a preset path, reducing the need for manual input. This design simplifies the operational steps while enhancing user immersion.

Virtual Environment Construction and Optimization: This proposal suggests constructing virtual environments that are inspired by real-world natural attractions, such as forests, lakes, and gardens, which are known to have therapeutic effects on emotional well-being. In addition to these realistic representations, surreal elements like religious pilgrimage sites or culturally significant locations can be integrated to cater to the diverse emotional needs of elderly users. Research has demonstrated that familiar and tranquil natural environments can significantly alleviate psychological stress [5]. To enhance immersion, dynamic 3D sound effects—such as birdsong and flowing water—will be used to create a calming auditory landscape, further promoting emotional healing. The goal of this design is to maximize user engagement and emotional resonance, allowing elderly individuals to experience the psychological benefits of nature even in a virtual setting.

User Feedback Mechanism and Interaction Optimization: The feedback mechanism in this system is designed to simplify user interaction, considering the cognitive and physical limitations of elderly users. A proposal for incorporating gaze-based interaction and subtle haptic feedback (such as gentle vibrations when an option is selected) aims to minimize the complexity of traditional input devices. Head movement recognition technology will also be included, allowing users to confirm actions through intuitive gestures like nodding. This natural interaction method reduces reliance on manual inputs, which can be challenging for users with mobility issues. High-contrast interface designs and adaptable icon sizes are also proposed to ensure accessibility and ease of use, addressing the visual and cognitive needs of the elderly population. By integrating these features, the system not only improves usability but also fosters a more inclusive and stress-free experience for the target demographic.

Ergonomic Design Based on Target Position: Eye-tracking calibration can be time-consuming and prone to errors, especially after head movement. Drift is a common issue, which may be improved through multiple or dynamic calibrations [17]. Ergonomically, the system focuses on positioning interactive targets within a comfortable range, avoiding extreme head movements that could cause neck or shoulder strain [10]. This reduces physical discomfort and extends the user's sustainable usage time.

4.4 User Experience Optimization and Testing

To ensure the feasibility and effectiveness of the system, MoodLink XR will conduct testing and optimization in the following areas:

Eye-Tracking Accuracy and Sensitivity Testing: Testing the accuracy and sensitivity of eye-tracking functions in different elderly user groups will ensure that the system can adaptively adjust based on users' physiological characteristics, avoiding operational errors or interaction delays.

Visual Stability Testing in Virtual Scenes: Testing the effects of scene transitions and movement speed in vir-

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tual environments on elderly users' motion sickness will ensure that virtual experiences are smooth and natural, reducing visual fatigue and the risk of dizziness.

System Usability and User Satisfaction Evaluation: Extensive testing with elderly users will evaluate the overall usability and ease of operation of the system, gather feedback on emotional healing effects and social interaction experiences, and use the feedback to further optimize system design.

Calibration Program Optimization: For users who have difficulty concentrating, traditional calibration programs can be time-consuming and prone to failure [18]. Dynamic calibration techniques can simplify the process, though the quality of the data still needs improvement [19]. In the testing phase, researchers will explore ways to improve the calibration process and enhance ease of use for elderly users.

Physiological and Psychological Feedback Testing: During user experience testing and system optimization, a combination of subjective and objective measurement methods will be used. In particular, physiological feedback (such as blood pressure and heart rate) will be used to monitor elderly users' responses to different virtual environments [13].

User Experience and Ergonomic Optimization Testing: To ensure long-term comfort, the system will dynamically adjust target positions based on user feedback. Physiological monitoring, such as electromyography and posture tracking for the neck and shoulders, will assess muscle activity and fatigue, ensuring the system reduces physical strain during extended use [10].

4.5 Anticipated Social and Emotional Impact of the System

MoodLink XR not only focuses on technical implementation but also considers the social and emotional impact of the system on elderly users. Through virtual reality technology, elderly users can enjoy natural landscapes they may miss due to mobility limitations, helping to alleviate loneliness and psychological stress. The system also includes virtual social functions, allowing elderly users to interact with others in the virtual world, such as touring virtual attractions together, sharing experiences, or engaging in social activities. These functions can help strengthen social connections among the elderly and enhance emotional support.

The system also provides opportunities for intergenerational interaction, allowing elderly users to invite family members from different locations to participate in virtual activities. This feature not only strengthens the bond between family members but also provides additional support for the elderly during emotional healing.

4.6 Future Directions and Technological Gaps

Although the MoodLink XR design has fully considered the needs of elderly users, future research needs to explore and develop several key technological areas:

Adaptive Interaction Design for Elderly Physiological Characteristics: Current interaction designs still need further optimization, particularly to address the cognitive and physical responses of elderly users. Future research should focus on reducing operational complexity and avoiding cognitive overload.

Scientific Validation of Psychological Health and Emotional Healing: Although MoodLink XR has designed virtual emotional healing functions based on the literature, larger-scale clinical studies are still needed to verify their long-term effectiveness, particularly in comparison to traditional therapies.

Enhancement of Virtual Social Functions: Future XR systems should further enhance virtual social functions, providing more interactive and emotionally supportive virtual spaces to meet the social needs of elderly users. Online social features could offer elderly users emotional support networks. Additionally, incorporating haptic feedback could allow elderly users to experience physical contact with virtual characters [16].

Data Privacy and Security: Eye-tracking data contains users' biometric information, such as iris patterns, which can be used for biometric identification [16]. Protecting the privacy of eye-tracking data will be a key area of future technological development.

Potential Harm from Infrared Radiation: HMD-based eye trackers use infrared light to enhance contrast between the pupil and iris. However, prolonged exposure to infrared radiation may pose potential harm to users' eyes [20]. It is important to consider the long-term health impact of eye trackers on elderly users, particularly how to reduce the potential risks of infrared radiation in system design.

5. System Design and Interaction Mechanisms

5.1 Gaze Navigation Mechanism

To reduce reliance on manual operations, the system is designed with a gaze navigation scheme. Users control their perspective by moving their eyes and activate an automatic path-following function by gazing in a specific direction. Research shows that eye-tracking technology can effectively reduce users' interaction burden, particularly for elderly users with mobility limitations [9]. However, current technology still faces challenges in terms of accuracy and responsiveness, especially when the gaze moves to the periphery of the visual field, where accuracy significantly decreases [17]. Therefore, future systems need to optimize the precision and stability of eye-tracking to ensure that elderly users can continue to enjoy a smooth experience during prolonged use.

Additionally, to prevent motion sickness caused by rapid perspective shifts, the system is designed with slow movement speeds and stable visual content to reduce sensory overload and ensure a comfortable experience for elderly users [12]. This design not only simplifies operational steps but also enhances user immersion and interaction efficiency.

5.2 Interaction Feedback Mechanism

To enhance emotional healing for elderly users, MoodLink XR incorporates virtual natural landscapes characterized by tranquility, refuge, and prospect. These environmental features have been shown to have significant effects on psychological recovery for elderly individuals [21]. By recreating familiar natural landscapes and providing soft auditory feedback (such as birdsong and the sound of running water), MoodLink XR can effectively alleviate users' psychological stress.

When users focus their gaze on an interactive option, the system provides subtle vibrations to remind them that the option has been selected, further simplifying the operational process. Additionally, the system supports selection and navigation through head movements (such as nodding for confirmation or shaking the head to cancel). Research shows that head movement recognition technology is highly accepted among elderly users and can effectively reduce reliance on manual input [8]. The interface's high-contrast design ensures that users can clearly identify important prompts, enhancing the system's usability.

5.3 Scene Interaction and NPC Design

Social interaction within virtual environments is crucial for emotional healing in elderly users. Research indicates that social interaction in virtual reality can significantly improve elderly users' psychological health, particularly in reducing loneliness and enhancing emotional support [2, 22]. Non-player characters (NPCs) can not only provide information but also simulate social scenarios from real life, enhancing user immersion [23]. For example, virtual tour guides or tourists can accompany users on virtual tours, providing explanations or engaging in simple conversations. This design effectively alleviates the loneliness elderly users may feel in virtual worlds, increasing the engagement and enjoyment of interactions.

The design of multi-user online functionality also offers elderly users opportunities for virtual socialization. Virtual social interactions can help elderly users find social support within virtual environments, and group interactions can enhance emotional resonance (Pauw et al., 2022). For example, users can tour virtual attractions with family members or friends, sharing experiences and further enhancing social connections.

6. Future Directions

As XR technology continues to advance, the application of virtual and augmented reality will further expand, especially in emotional healing and psychological health. Future developments will focus on the following areas:

First, advancements in emotion computing will enable more personalized emotional support within XR systems. By integrating sensors that monitor heart rate, facial expressions, and voice, combined with machine learning technologies, future XR systems will be capable of recognizing and responding to users' emotional states in real-time. This real-time data will allow systems to dynamically adjust virtual environments and offer valuable insights for tracking and evaluating long-term emotional healing progress.

Second, virtual social functions will be further optimized and expanded to enhance multi-user interaction experiences. For instance, introducing virtual social networks could provide elderly users with a broader social support system, helping them maintain social connections within virtual worlds. Additionally, future XR systems may integrate physiological feedback mechanisms to help elderly users better adapt to virtual environments and avoid potential physical discomfort [16].

Finally, data privacy and security will be a key focus for future developments. Technologies like eye-tracking involve users' biometric data, which requires strict privacy protection measures. Future XR systems should employ encryption and biometric security mechanisms to ensure that user data is not misused [24].

7. Contributions and Advantages of the Project

7.1 Social Contributions

MoodLink XR offers a novel solution to address the psychological health challenges posed by global aging by designing an emotional healing XR system for elderly individuals. Through immersive virtual natural landscape experiences, elderly users can alleviate loneliness and enhance psychological well-being. Additionally, this system provides elderly individuals with mobility issues an alternative to real-world travel for emotional healing, helping them reintegrate into society. This not only improves the

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quality of life for the elderly but also provides opportunities for intergenerational interaction, strengthening family bonds.

7.2 Technical Contributions

In terms of technology, MoodLink XR proposes an innovative solution that combines eye-tracking, head movement control, and virtual natural landscapes to simplify interaction for elderly users. By optimizing eye-tracking and ergonomic design, the system reduces the physical burden on elderly users, improving comfort during long-term use. Additionally, MoodLink XR integrates multimodal emotion computing into XR systems, providing valuable experience and technical foundations for future personalized emotional healing systems.

8. Conclusion

This study introduces an innovative home-based XR art experience system by applying Extended Reality (XR) technology to the emotional healing of elderly individuals with mobility issues. Through the combination of virtual natural landscapes and eye-tracking technology, this system provides an effective tool for emotional healing in the home environment. The research demonstrates that elderly users can experience emotional healing effects similar to real-world natural landscapes within virtual environments, significantly alleviating psychological stress and loneliness.

In the future, with the further development of multimodal emotion computing, data-driven design, and personalized virtual environments, MoodLink XR is expected to become a comprehensive psychological health management platform, providing ongoing emotional support for elderly individuals and other special populations. By continuously optimizing and expanding the system, XR technology will be widely applied in emotional healing, bringing greater benefits to society.

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