


Review

Potential of Augmented Reality and Virtual Reality Technologies to Promote Wellbeing in Older Adults

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Abstract: Older adults face significant loss and limitations in terms of mobility, cognitive ability, and socialization. By using augmented reality and virtual reality technologies they have the potential to overcome such loss and limitations, and to eventually improve their quality of life. However, this group is often excluded in augmented reality and virtual reality deployment. Further, limited studies address their challenges when using augmented reality and virtual reality. Therefore, for a critical review of augmented reality and virtual reality for older adults, we developed a framework to evaluate related factors, including physical, social, and psychological wellbeing. Through the critical review, we identified that most augmented reality and virtual reality studies focus on physical wellbeing of older adults but also make substantial efforts to increase their psychological wellbeing. Fun factors that would motivate them are also extensively considered. Further, social isolation continues to be a significant issue for older adults, but the appropriate content to increase their social wellbeing is insufficient, although many commercial products have been developed. The contribution of the present study is to provide a contextual framework and an evaluation framework for the critical review of augmented reality and virtual reality technologies to promote wellbeing in older adults. This study also suggests the augmented reality and virtual reality research direction for studies on this group by identifying the research gap through the critical review process. Lastly, this study investigates design directions of augmented reality and virtual reality for older adults by introducing challenges and design issues that emerged through the critical review.

Keywords: augmented reality; virtual reality; older adults; wellbeing; evaluation framework

1. Introduction

Long life expectancies and dropping birth rates have resulted in changes in world demographics over the past two decades [1]. Coupled with this change in demographics, the past decades have witnessed a substantial increase in the use of technology in all aspects of daily living. Various studies are being conducted and thousands of new technologies are being developed to remedy issues that older adults might experience regarding physical and mental abilities, and eventually improve their quality of life [2,3]. Recently, as an alternative technology for older adults, positive technology has emerged and is receiving attention. Positive technology ultimately aims to improve the overall quality of life by promoting human wellbeing, satisfaction, and contentment, rather than only focusing on device usability [4]. Grossi et al. [4] classify the positive technologies affecting human wellbeing into three aspects—physical, emotional, and social levels—and provide a comprehensive overview of the positive technological progress. Acampora et al. [5] explore the application of ambient intelligent

(AmI) systems in the health care domain from various perspectives. They believe that AmI systems have the potential to facilitate individuals in leading a healthier lifestyle and to enhance physical wellbeing. Their study deals with challenges of AmI and research directions. Concern about the impact of long-term exposure to an environment in which many sensors are embedded, security or infrastructure issues, and social and ethical issues are introduced as the challenges AmI should overcome. Luneski et al. [6] present the potential benefits of research in affective computing (AC). AC in their study investigates the relationship between human emotions and computers, which has a positive impact on social, cognitive, physical, and other human behaviors. This study also reviews the general state of the art in AC applications in the health care domain. Tapus et al. [7] conduct a review on the way in which a robot understands the natural interaction between people and responds to that correctly from various perspectives. Broadbent et al. [8] review the potential user's needs and expectations as regards a robot's help in relation to the independence of older adults and improvement of health outcomes. Using robots has been proposed as a way to support physical, social, and emotional wellness. However, despite the significant potential of AR and VR technologies to improve the quality of life of older adults, and their emergence as new technologies, very few papers review AR and VR studies on older adults and the literature on this topic is thus insufficient.

Augmented reality (AR) and virtual reality (VR) technologies have been rapidly employed in a range of contexts, including gaming, navigation, medicine, education, and design [9,10]. Cipresso et al. [11] collected all the articles about VR and AR in the Web of Science Core Collection scientific database. They conducted a computational analysis to show the evolution and development of VR and AR research over time [11]. According to Zion Market Research [12], by 2021, the AR market size will exceed US \$133.78 billion and that of VR is expected to reach \$75 billion. Thus, compared with the VR market, the AR market would grow much more rapidly; however, the VR market would also tend to increase steadily. AR combines virtual information with information on the physical environment on a real-time basis [9,13]. VR technology delivers computer-generated simulations of 3D virtual environments that users experience by wearing a VR headset [10]. The main difference between the two is that AR integrates the virtual and real worlds, while VR offers complete immersion into a simulated environment and is entirely digitized. AR and VR are typically associated with younger populations, since these are sophisticated technologies, perceived as most suited for gaming platforms, and have characteristics such as being complex to set up and use. Therefore, older adults are often excluded in the development of VR and AR technologies. There is a lack of solid evidence that adopting AR and VR technologies is effective in the long run. The biggest barrier to wide adoption of these technologies is the lack of good user experience design and ergonomic issues.

Many designers and researchers realize that AR and VR technologies have the potential for improving older adults' social relationships, wellbeing, and quality of care and facilitating their independence [10,14,15]. For successful aging and wellbeing, a variety of factors should act together, such as avoiding disability or disease, maintaining physical and cognitive functions to be healthy, retaining intimate human relationships, participating in diverse activities actively, and maintaining interest in social activities [16]. Older adults are a very diverse group covering a wide age range and have varied characteristics, behaviors, and needs. Typically, when people age, they experience a significant decrease in their physical, cognitive, and sensory capabilities, and many of them might have negative attitudes toward technological innovations [17,18]. One of the many stereotypes around aging is that seniors are resistant to new ideas and advances in technology. Older adults express less comfort in using technology and less confidence in their ability to successfully use these systems. These unique physical and cognitive characteristics could act as interference factors for their engagement in using AR and VR technologies. Many challenges exist in the process by which they develop interest in, give attention to, and therefore, easily use, AR and VR technologies.

Current studies of AR and VR technologies for older adults are limited because they focus on how to enhance innovative designs and usability [9,19,20] with little regard for the potential older adult users. Efforts to conduct research on them are often hampered by lack of understanding of

the abilities, requirements, and preferences of this population. The present study suggests that it necessary to explore further the challenges older adults face currently and the related design issues of VR and AR, considering the balanced physical, emotional, and psychological wellbeing of this group. This study critically reviews AR and VR technologies, using an evaluation framework consisting of three categories: physical, emotional, and psychological wellbeing. Through this review, we examine the challenges and barriers in the use of AR and VR based on the characteristics of older adults and discuss emerging design issues and future directions. Because of the natural characteristics of these individuals, accurate understanding of likely challenges would make it possible to provide them better design and user experiences. Ultimately, AR and VR technologies should be designed to promote wellbeing by improving their overall quality of life.

2. Related Works

2.1. Age-Related Factors that Influence the Use of VR and AR Technology

Many researchers in the area of human–computer interaction and gerontology have focused on age-related factors that influence technology utilization. When designing technology for older adults, age-related changes in cognitive and physical abilities are critical considerations [21]. The technology for them is developed to combat their age-related decline, and there is a tendency to provide poor user experiences that make it difficult for them to use such technology. Since older adults are not familiar with the interaction modality, devices, and virtual experiences used for VR, it is important to understand affecting age-related factors when developing the system. However, in developing VR and AR, studies have not actively attempted to ascertain the characteristics of these individuals that influence usability of these technologies.

Older adults often exhibit unenthusiastic feelings about using technology owing to health or disability concerns [22]. The aging process causes gradual losses to the sensory systems, such as vision, hearing, and motor systems [18]. Physical and sensory limitations impair their ability to receive information or understand design elements and this decline varies widely among individuals [23,24]. The attitude of older adults tends toward the negative, considering the effort needed to learn how to utilize a computer effectively and this reduces their willingness to explore how technology works [25]. The need for cognitive abilities is essential, given the complexity of technology [26,27]. Older adults are required to utilize heightened working memory resources and effort, thus affecting their utilization of new technologies [24,25]. The fear of technology is often informed by their concern that they lack control over the activation and deactivation of the system [22]. They have poor ability to be immersed in something new or unfamiliar because of the lack of attentional capacity. Several behavioral inefficiencies of older adults while using AR and VR technologies are attributed to changes in their cognitive abilities.

Considering negative emotions is necessary when designing VR and AR applications for older adults. Eisma et al. [28] indicated that older adults convey negative self-efficacy, thus feeling too old to adopt new technology. Peek et al. [29] argued that the utilization of new technologies by older adults is heavily influenced by their stereotypes and expectations. In certain cases, stereotypes work to the disadvantage of the users, affecting their performance, motivation, and emotions. It can thus be said that affective states, such as enjoyment and fun, are very critical to user involvement when designing AR and VR technologies. Older adults have not been exposed to the same level of technology as the younger generation [30]. This results in older adults not having an accurate mental representation or conceptual model of how interactive technology works, or what it can and cannot do [31]. Understanding mental models of elderly users leads to improved understanding of their needs, expectation, and requirements as regards using current technologies. The present study does not simply list their characteristics, but introduces factors having an effect when older adults use VR and AR. These factors would become the foundation of understanding VR and AR for older adults and could be considered in the design process. As for cognitive decline, it is necessary to understand the

fundamental age-related characteristics that lead to such decline. However, it is not easy to understand such characteristics or apply them in the design process. Thus, we conduct this study to properly understand the age-related characteristics of older adults through a literature review, determine the importance of the cognitive elements, and examine their cognition in depth. These elements are expected to be the factors that should be considered in developing AR and VR for this group.

2.2. AR and VR Technologies to Promote Wellbeing of Older Adults

Various studies have been conducted on healthy aging for the purpose of increasing the average healthy life of older adults. However, in reality, studies on diverse technological interventions are still insufficient to optimize their physical, psychological, and social wellbeing [32]. The studies on emerging technologies for them mainly focus on supporting mental or physical health and wellbeing in later life. Forsman et al. [32] indicated that it is important to balance physical, psychological, and social wellbeing to promote active and happy aging. VR and AR are emerging technologies that are increasingly integrated into our everyday lives, from entertainment to healthcare. Even though VR and AR have huge potential as technology-based interventions to promote and maintain overall wellbeing of older adults' life, studies related to this group have not conducted actively.

VR allows older adults to be fully immersed in the virtual environment, isolated from real-world circumstances, by using devices such as haptic controllers [33,34]. AR provides virtual experiences to users, by keeping the real world in the center and layering digital information. An advantage of VR and AR is enabling users to have tremendous experiences of a new world; thus, older adults have an immersive experience of some places, which they could not otherwise visit because of their physical impairment and reduced mobility, without having to spend time and energy. VR gives a full, detailed view of a place, which makes it more interesting and engaging to older adults. Another advantage of VR and AR is to allow them to receive risk-free training. That is, they provide new, safer ways to simulate practices for cognitive and physical training for older adults, without exposing them to hazardous environments. One disadvantage is that overuse of VR and AR lead to older adults having difficulty in distinguishing between real and virtual worlds. The most difficult challenge to them in using VR is to implement the system, and thus, they need one-on-one assistance to use such technologies. Above all, VR and AR allow communicating and building relationships with others in the virtual world. However, communication using VR or AR should not replace human interaction. Some older adults might have concerns that using these technologies can take away an important aspect of social interaction in real life.

Despite such advantages and disadvantages, it is difficult to dispute the fact that VR and AR are interesting enough to attract attention from older adults. Since VR and AR technologies can be an intervention for improving their wellbeing [35], such applications are increasingly employed in the healthcare domain for assessment, training, and rehabilitation of older adults with different disorders. Many studies have indicated that VR and AR applications have good potential of improving the treatment of health-related issues and the quality of life significantly. Most of all, VR and AR offer many opportunities to have enjoyable experiences. Physical and cognitive training can be boring, tiring, and un motivating for older adults, and thus, several interactive games using VR and AR are developed to motivate them to use these [36]. Since VR interactive games have a fun factor, such games are used as a complementary tool in rehabilitation to enrich older adults' practical activities. In addition, AR and VR will be new platforms for new types of social interaction [37]. They provide some opportunities for various social interactions to older adults, who have been reluctant to engage in such interactions owing to their physical disabilities. VR has been utilized to enhance the ability to perform activities of daily living, such as taking medications, preparing meals, remembering tasks to do, and using navigational skills in ambulation and driving [38]. VR and AR applications are widely used to make their life better and convenient. However, few studies have examined the effects of a virtual environment on emotions, thoughts, and behavior of old adult population. Thus, it is necessary to

properly understand their traits and apply these in the design process, to help them benefit from using AR and VR effectively.

3. Methodology

3.1. Selection

Various innovative technologies, including the use of VR and AR, are being applied to support older adults' wellbeing. We primarily conducted our search through Google Scholar, using terms that included multiple ways of describing older adults (e.g., "older adult"; "senior"; "elder"), "virtual reality" and "VR"; "augmented reality" and "AR"; "health and wellness"; "fun"; "independent living"; "social"; and "technologies to support healthy aging." We reviewed other sources, including reports, websites, and relevant newspaper articles, to conduct a critical review of VR and AR focused on older adults' wellbeing. News outlets and popular media channels display many commercial products; however, it was relatively difficult to find a substantive amount of formal literature about AR and VR technology for older adults in this area. To identify further the potential of applying AR and VR for them, we reviewed related articles, including those on AR and VR application and issues of aging populations. Among articles on AR and VR for older adults, 30 were selected, and 15 of these articles were excluded because these were cases focusing on only technical aspects to realize virtual experiences of VR and AR, or cases that are applied only under professional conditions, such as a hospital; we excluded such articles even if regarding a health care system for older adults. We reviewed 15 publications since 2000 investigating both AR application and the aging population.

3.2. Contextual Analysis

We developed a contextual analysis framework for the first stage of the critical review, aiming to extract principal factors that focused on older adults' wellbeing in the use of AR and VR (Table 1). As for the analysis framework, six elements comprising AR architecture (user, interaction, device, virtual content, real content, and tracking) which Liang [9] introduced, were modified for this study's purposes. The categories were divided into five divisions: Domain, User, Device, Interaction, and Virtual Experiences.

Table 1. Contextual analysis of Augmented reality (AR) and virtual reality (VR) factors from each application.

| Applications | AR and VR System Architecture | | | | |
|--|-------------------------------|---|--|---|---|
| | Domain | Elderly User | Devices | Interaction | Virtual Experience |
| Aging and avatar Cyarto et al. [39] | Society | Need social activity | VR headsets, Microsoft Kinect motion sensing camera, large display | VR, Natural Gesture | Having social interaction in virtual environment |
| Nacodeal project Saracchini et al. [40] | Society, Convenience | Need assistance in daily activity | Mobile device, wearable device with pico projector, sensors | AR, Natural Gesture, Mobile Interaction, Projection | Obtaining virtual information |
| Indoor biking Bruun-Pedersen et al. [41] | Health, Fun | Need exercise | Bike, large display, speaker, desktop, Arduino | VR, Natural Gesture | Being motivated to exercise, viewing virtual landscapes while user moves |
| Drinking Water [42] | Health, Convenience | Need healthcare reminder | Desktop, VR headsets, mobile, wearable device | AR, Natural Gesture, Projection, Mobile Interaction | Receiving virtual information |
| Rehabilitation Lee et al. [43] | Health, Convenience, Fun | Need health training | VR headsets, position sensor, tangible controller, desktop | VR, Natural Gesture | Performance testing, training cognitive functions |
| AR-3DH Lee et al. [44] | Health, Fun | Need training for mental rotation ability | 3D modeling, rendering, animation software, leap motion, | AR, Natural Gesture | Learning navigational skills, having fun by adding gaming factors, obtaining 3D hologram visualization |
| Eldergames Gamberini et al. [45] | Health, Fun, Society | Need mental training, fun | Tabletop display, tangible controller, cameras | AR, Natural Gesture, Tangible Interaction | Playing a mental game with other elders |
| Rehabilitation Korn et al. [46] | Health, Fun | Need support rehabilitation activities | Micro projector, sensors, mobile, | AR, Natural Gesture | Having gamified/individualized movement therapy |
| 3D ARS Dal Jae Im et al. [47] | Health, Fun | Need support rehabilitation activities | Kinect Xbox 360, screen | AR, Natural Gesture | Having gamified training for balance and mobility |
| V-Time Mirelman et al. [48] | Health, Fun | Need support rehabilitation activities | Microsoft Kinect motion sensing camera, display, | VR, Natural Gesture | Having gamified exercises for fall risk reduction |
| Aloha [49] | Fun, Society | Need more fun, relax, social | VR head-mounted display | VR, Natural Gesture | Virtually exploring places without physical visit |
| Gesture-based AR game McCallum and Boletsis. [50] | Fun | Need more fun | AR glasses, mobile, leap motion | AR, Wearable, Gesture-Based, Mobile Interaction | Playing a game with the manipulation of digital objects (Similar to the “Angry Birds” game) |
| CogARC Boletsis and McCallum. [51] | Health, Fun | Need cognitive training | Vuforia AR SDK, screen with rear-facing camera | AR, Tangible Interaction | Playing a game for cognitive training and screening |
| Assistive navigation Hervás et al. [52] | Convenience | Need support daily activities | Google map API, mobile | AR, Mobile Interaction | Guiding spatial directions according to the user context, monitoring, reminding the user of daily tasks |
| Driver hazard perception Schall et al. [53] | Convenience | Need to safely drive | SIREN, a four-channel display, speaker | AR, Driving | Providing information about the detection of hazardous target objects |

Through the critical review of these 15 publications, we found that AR and VR applications for older adults could be mainly classified into four domains: Health, Social, Fun, and Convenient. The user in AR and VR environments is the individual who has direct control of the system and who directly undergoes virtual experiences; the users considered in the present study were older adults. There are various types of older adults: those who are socially isolated, have physical problems and mental impairment, require aid in daily life, and find new and interesting activities. It is necessary to examine the class of older adults for whom AR and VR systems have been developed. Within the virtual world, a device is a carrier or object that makes it possible to realize users’ vivid virtual experiences. It can take the form of a mobile phone, tablet, desktop computer, handheld device, etc. [37]. All AR devices incorporate three basic functions: displays, processors, and sensors [9]. For a great VR experience, VR headsets, head-mounted display, high-end computers, and a high-end processor will be needed to assist in positional tracking and control the real and immersive virtual environment [33]. Older adults do not easily undergo virtual experiences, because of the price of the devices required for the experiences. They have difficulty in setting up the devices and feel uncomfortable in always wearing the devices, although the devices tend to be light. Such problems should be considered in depth when finalizing the devices to be used to support their VR experiences.

Since immersive experiences should be designed for AR and VR deviating from 2D GUI design, interaction designs are required that consider behavioral characteristics of older adults. AR and VR use natural gestures used for daily living, and not any specific pre-assigned gesture. Designers and researchers should consider ways to enhance perceived affordances to create intuitive and natural user interfaces for AR and VR. In addition, it is necessary to consider the content provided to older adults in the virtual environment. Some insights on the content considered to attract them can be acquired. The VR system explains a computer-generated world of imagery, while AR contains virtual and real content. Virtual content can be in the form of various modalities, including 3D animation, text, audio, 2D images, and even vibrations. The selected papers represent how to create immersive 3D content for AR and VR that provides engaging and interesting user experiences. The 15 selected papers were analyzed by five components (domain, user, device, interaction, and virtual experiences) of AR and VR. This analysis is a basic work to extract factors comprising the evaluation framework in Section 3.3.

3.3. Evaluation Framework

We developed the evaluation framework by analyzing components of VR and AR through the contextual analysis and extracting factors to observe ways in which each application is used for older adults and the related effects on their life (Table 2). We identified the critical factors of VR and AR focused on promoting their wellbeing. Wellbeing is the experience of health, happiness, and social interactions. Many immersive technologies are developed to serve older adults’ needs and facilitate ease of living and happiness for this population. The categories for evaluation framework were mostly in three divisions: physical, social, and psychological wellbeing.

Table 2. An evaluation framework of AR and VR, focusing on promoting wellbeing of older adults.

| Category | Factors | Clarification |
|--------------------|---------------|--|
| Physical Wellbeing | Motivation | Encouraging and engaging older adults so that they have interest in, and concern for, physical activities |
| | Training | Training to perform physical activities that older adults are reluctant to do because of their risks/or increasing fundamental physical strength |
| | Reminder | Providing virtual information that is helpful for health of older adults in various ways, in real time and constantly |
| | Accessibility | Good accessibility for older adults to use AR or VR technologies/or minimizing physical difficulties that incidentally occur while older adults use the system |

Table 2. Cont.

| Category | Factors | Clarification |
|-------------------------|------------------------|---|
| Social Wellbeing | Remote participation | Providing contexts for older adults to participate in social interactions anytime, anywhere without concern about mobility |
| | Virtual interaction | Providing environment to share experiences and to build relationships with other people, such as through human-to-human interaction in the virtual environment |
| | Emotional relationship | Making older adults not feel a sense of difference in emotion in the process of socialization in the virtual environment |
| | Community services | Providing services to avoid inconvenience in sharing and using virtual devices with other people/or serving and supporting the diverse activity potential while using AR and VR systems |
| Psychological Wellbeing | Positive emotions | Arousing positive emotion continuously in the environment using VR and AR |
| | Virtual content | Updating content to retain users' interest constantly, not temporarily |
| | Independence | Supporting the needs of older people living independently in residential homes and/or assisted-living communities |
| | Environmental mastery | Providing the ability to manage environmental factors and activities in an environment in which VR supports daily activities |

Through the contextual analysis, we found that several studies have indicated that VR and AR show promise in treating pain, training for physical ability, motivating and encouraging for physical exercise, and reminding about medication to improve the functioning of the body. Many studies highlighted that the incorporation of the smartphone into the technology makes VR and AR accessible and relatively cheap. The critical factors were for enhancing physical wellbeing: motivation, training, reminding, and accessibility. In addition, AR and VR have been widely used to decrease feelings of loneliness and depression by allowing users to participate in social activities and interact with others remotely in the virtual environment. Socialization, which is crucial for older adults, has a positive impact on their mental and physical health, and we identified subcategories for supporting social wellbeing: remote participation, virtual interaction, emotional relationship, and community services. VR and AR also enable older users to have good user experiences, and thus develop positive mental states, by providing fun gaming experiences and enabling them to be independent. VR and AR allow older adults to not only practice daily activities but also give them an opportunity to have unusual experiences. The critical factors for promoting psychological wellbeing include positive emotions, virtual content, independence, and environmental mastery. The evaluation framework for AR and VR for older adults enabled a critical review of selected papers.

4. Critical Review of AR and VR Technologies for Older Adults

4.1. Physical Wellbeing

Physical wellbeing of older adults refers to the state in which they are capable of performing physical activities or social roles; further, a series of these activities should be free from physical limitations. Physical wellbeing is an important issue in AR and VR studies, encompassing "motivation," "training," "reminder," and "accessibility." VR and AR are concerned with four types of perspectives to support physical wellbeing of older adults. First, training for their lack of ability; second, encouraging an interest in physical activity, applying an engaging factor to the design; third, providing a reminder related to health combined with interaction modality, such as a wearable or mobile device, and lastly, providing good accessibility for them to use AR or VR technologies.

VR and AR applications have the merit of simulating various situations for health training and performance testing [46–48]. Lee et al. [43] created a virtual supermarket through which they explored the potential to use VR technology to assess and train the cognitive aptitude of brain-injured patients with regard to assistive daily living by asking them to complete basic shopping tasks. Lee et al. [44] developed an AR-3DH system designed to train older adults to refine their mental rotation skills.

Korn et al. [46] and Dal Jae Im et al. [47] designed a system combining AR and gamification to support elderly persons' rehabilitation activities. Among older adults with a mental problem, even a small mistake may lead to a severe accident. One main advantage of using AR and VR for enhancing physical wellbeing is that these applications enable them to engage in physical training in a safe environment.

Many nursing homes and older adult facilities offer residents physical therapy as part of the daily exercise options. Many older adults are opposed to exercises that involve physical activity. VR and AR applications can represent novel systems through which they modify their negative perceptions of exercise and learn to enjoy it. Bruun-Pedersen et al. [41] described that some form of fun factors must be included in exercise to motivate people to engage in physical activity. They performed a study that involved placing exercise bikes in front of large screens. As the users pedaled, the screens displayed virtual landscapes that the participants rode through at speeds that were aligned with their output on the bike. This study showed positive indications that a recreational virtual environment augmentation could motivate subjects to exercise more than before.

To enhance physical wellbeing of older adults, training with engaging factors to motivate physical activities is important. We found six applications applying gaming factors for preserving cognitive and physical functions impaired by aging. The Eldergames project [45] is a gaming platform using a tabletop and mixed reality solution aimed specifically at preserving cognitive functions and providing pleasurable experiences to elderly people. The Cognitive Augmented Reality Cubes (CogARC) system [51] presents a game-based cognitive training experience that uses an AR-based approach through which people can interact with physical and tangible objects (in this case, cubes). These studies highlighted that it is important to motivate and engage older adults through the gaming factor.

Mobile apps are commonly used to set reminders for medication, and wearable devices are widely used to track activities. Virtual feedback augmented on real objects based on user activity data is much more effective for giving them a reminder than are mobile apps. The significant advantage is that it can be used by applying various scenarios, once people learn how to use the system. For example, Ergosign Labs [42] designed a system that reminds people to drink water, using two wearable devices. With the help of a smart bracelet and AR glasses combined, they want to create an assistance system for older adults that supports their daily living in a subtle and meaningful way. Various studies are needed on ways of designing a virtual environment that can draw older adults' interest. Intriguing content can increase their interest in exercise. Because VR and AR heavily rely on the physical component of the interaction, often requiring full body interactions and physical space as a form of user input, designing for accessibility is crucial to the operation of the system. Only a few papers mentioned accessibility. More studies need to be conducted to understand user accessibility in combination with the usability design of the hardware, as well as user experience design.

4.2. Social Wellbeing

Social wellbeing is the extent to which older adults feel a sense of belonging and feel less lonely and depressed through using technologies. VR and AR can be treated as powerful tools for promoting socialization among them. The following four critical perspectives are considered: remote participation, virtual interaction, emotional relationship, and community services.

Decline in mobility, lack of transportation, and financial constraints are just a few of the common challenges faced by older adults who long to participate in community events or experience new places. As technologies continue to evolve, innovative ways of using these for social participation will continue to be developed. VR and AR provide them an opportunity to explore places that they cannot physically visit, and allow them to connect and engage with others. The VR and AR experiences can help build connections and an emotionally rich social experience. First, as a system, a virtual environment is used for the purpose of older adults' social activities and exchange. The Aging and Avatar research project [39] by Microsoft Research Center investigated how full-bodied gesture-based interactions and avatars can be used to create a sense of virtual presence between older people who are unable to meet face-to-face. The virtual experience helps build conversation and socialization naturally

because participants are together in the experience. Several challenges can prevent access to AR-based activities, such as the need to use specialist equipment, the requirement for assistance, and differences in the time zones in which the various people involved in a given activity are based. This is a new way of representing visual feedback for older adults. This research indicated that personal help or community services are important to preclude any sense of isolation and reduce their stress while interacting with the system.

Interacting with other people as an avatar who reflects on what one views in a virtual space can provide a more emotionally rich experience than a video call with a mobile device. Given a study of the experience leading to a sense of satisfaction or a positive impact on their life, an AR system can be utilized as an alternative to resolve social isolation. Some VR and AR applications in the social domain have been designed for the purpose of assisting with daily tasks or training for cognitive ability; however, it is expected that using this system will increase social interaction through the chance to communicate with other people. The Nacodeal Project (Natural Communication Device for Assisted Living) [40] employs an AR device that is worn around the neck. It provides participants with helpful advice and guidance that facilitates their ability to perform daily activities and access online services. The goal of the technology is to enhance social interaction and incite cognitive processes for members of the aged population living in an aged care facility. VR and AR can immerse users in a virtual world; as such, they represent powerful methods by which members of the aged population can engage in activities and social experiences. Social exchanges can be arbitrated through novel technologies that engender a sense of presence or consciousness of other people. Multimodal interactions can take a variety of forms, including facial expressions, body orientation, and gestures. Through these interactions, users can connect with others and develop a sense of intimacy. Thus, VR and AR can engender a sense of physical presence by enriching personal interactions with other people.

4.3. Psychological Wellbeing

Psychological wellbeing for older adults refers to emotional wellness and subjective wellness [54]. Arousing positive emotions, such as fun, happiness or satisfaction, while using AR and VR is an important factor when designing AR and VR. It is also crucial to support their insufficient ability so that older adults can lead an independent life. Psychosocial wellbeing includes the following four critical factors for this group: positive emotions, virtual content, independence, and environmental mastery.

We found that gamification, interest, and engagement factors are important in an AR system for rehabilitation. McCallum and Boletsis [50] developed an AR architecture that exploited the capabilities of gesture-based technologies to create more engaging games, such as a 3D version of the popular Angry Birds game. Boletsis and McCallum [51] created CogARC as an engaging tool that harnesses the powers of cognitive screening. The game environment is primarily designed to motivate and engage elderly players to play it frequently. The AR integration game successfully attracted older people. Boletsis and McCallum [51] published a paper in which they explored game content and highlighted the need to deliver content incorporating a motivating factor that maintained the player's interest; for example, adjusting the level of difficulty of the game.

Many studies focus on developing interesting virtual content to attract users. The Aloha VR program [49] aims to assist people to relax by offering calming environments. The immersive world offers an escape that allows older adults to forget their chronic pain, anxiety, and social isolation. It is necessary to consider activities that can be performed in a virtual environment, and not be content with simple appreciation of the environment; thus, an effort must be made to develop content in which older adults may be interested. Visual prompts, signifiers, and virtual feedback that allow them to have fun need to be identified. Designers and researchers should consider both positive and negative emotions of older adults. Boletsis and McCallum [51] described the need to consider age-related cognitive changes when designing a system for elderly users. System errors can easily confuse elderly people and cause negative feelings of uncertainty, confusion, and tension. As such, it is imperative to design the system to prevent errors and ensure that any errors that do arise can

be easily managed. Interaction issues, such as errors and complexity, may negatively affect users' perception, cognition, and emotional state, consequently having major effects on the targeted cognitive stimulation. Long-term motivation, engagement, and social interaction should be examined in further investigations of AR and VR applications.

Various VR and AR applications have been developed to support older adults' independence as regards mobility or driving. Four papers apply AR applications to support older drivers in terms of navigation and hazard perception. Kim and Dey [55] created a prototype with an AR navigation display system that is placed onto the vehicle windshield. They designed it to help elderly drivers, and initial research indicated that it significantly reduced the number of navigational errors by users compared with traditional navigation systems. The system created an easy way by which users could find their bearings and the name of the next street by viewing an AR display of their location. Hervás et al. [52] and Schall et al. [53] created AR indicators that employ a variety of virtual content for aged drivers. Traditional navigation systems are typically not very user-friendly. They frequently present information in nonintuitive ways and incorporate confusing commands that people are unable to understand unless they have good spatial orientation skills. Hervás et al. [52] concluded that in addition to providing users with a solution, the system incorporated social features that the friends and relatives can use to supervise the user. Thus, friends and relatives can assist the user if he or she becomes lost. They can also formulate navigational instructions to places of interest and add events.

Many VR and AR applications have been designed to assist physically disabled or older adults in their daily activities. Older adults often find it very difficult to operate their daily appliances, which other people might find very easy. Ullah et al. [56] suggested a VR- and AR-based application that could control home appliances through a touch-based smart home system that augments users' physical experiences. They concluded that it is important that VR and AR applications that are designed to increase convenience should consider aged people's general behavior patterns.

4.4. Summary

The overarching goal of the emerging technology developed for older adults is to assist them in tackling problems they encounter, and to design easy-to-use systems. A variety of factors, such as emotional, intellectual, social, and physical factors, play important roles together to improve the quality of life. When designing VR and AR, designers do not concentrate on only one effect. For instance, even in the healthcare VR and AR applications for physical wellbeing, gaming factors are designed to satisfy psychological wellbeing, and socialization is taken into account as an expected effect of using the system. For older adults, physical, social, and psychological wellbeing should be provided in a balanced manner. Table 3 presents the factors that the selected papers focused on in considering the wellbeing of older adults. The Harvey ball was used to interpret the degree to which each factor is mentioned in each paper. In case the ball is filled with black completely, it means that a specific factor is dealt with as an important factor in the paper. For example, we found that there is a correlation between the motivation factor that belongs to the physical wellbeing category and the positive emotions factor that belongs to the psychological wellbeing category. The papers mentioned that as regards AR and VR related to healthcare, it is important to arouse positive emotion by stimulating interest of older adults as a plan to motivate them. A critical analysis of selected VR and AR applications identified the types of fields in which studies are being conducted and the fields that require more in-depth studies to enable older adults to lead a balanced life. The analysis revealed that studies on AR and VR technology are being increasingly conducted to support physical and psychological wellbeing of older adults and that social wellbeing is the less studied area. At an older age, developing meaningful relationships with others and maintaining a social network to overcome loneliness is critical, and AR and VR can facilitate social wellbeing. Thus, more in-depth exploration of AR and VR for promoting social wellbeing is needed.

Table 3. Critical analysis of selected AR and VR applications.

| Category | Factors | [39] | [40] | [41] | [42] | [43] | [44] | [45] | [46] | [47] | [48] | [49] | [50] | [51] | [52] | [53] | Total |
|-------------------------|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|-------|
| Physical Wellbeing | Motivation | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Training | ☐ | ☐ | ☐ | ☐ | ● | ● | ☐ | ● | ● | ● | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Reminder | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Accessibility | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Social Wellbeing | Remote participation | ● | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ● | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Virtual interaction | ● | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ● | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Emotional relationship | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Community services | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Psychological Wellbeing | Positive emotions | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Virtual content | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Independence | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| | Environmental Mastery | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Note: Harvey balls ☐ ☐ ☐ ☐ ☐ represent “very poor,” “poor,” “average,” “good,” and “very good,” respectively.

5. Challenges and Design Issues of VR and AR for Older Adults that Are Associated with Age-Related Characteristics

To improve wellbeing for older adults, it is important to understand the challenges and barriers they face when using VR and AR technologies, and the reasons that they are hesitant to utilize those technologies. We identified a future research direction through the critical review using the evaluation framework. The research direction can be suggested through design issues that emerge by examining challenges likely to occur owing to the aging process and challenges older adults encounter even though the challenges could be less serious problems to a young generation.

5.1. Challenges and Design Issues for Physical Wellbeing

Older adults fear how other people perceive them. Porter [57] precisely stated that the fear of stigmatization is quite overwhelming. Therefore, they will be cautious when using or wearing devices, if the external appearance of a VR device resembles an assistance device for health, because they do not want other people to view them as frail, weak, or poor in health. As for installation of VR, it should not only be located at a place where it is easy for older adults to access, but their privacy should also be taken into account. It is essential to try to offer them a sense of comfortable use through overall understanding of the space where the system is used as well as the system design.

Notably, the fact that they must use wearable devices for VR applications may become a huge burden on older adults. The understanding of older adults who may be unwilling to wear wearable devices for a long time is required, and it is necessary to recognize that such a negative emotion would have a negative effect on use of the system. Motion sickness or dizziness, which they complain of in the process of using the system or after using it, can develop into a secondary disease for them. Therefore, constantly tracking their inconvenience is critical, because when designing VR applications, it is necessary to consider how well they are able to accept the virtual environment. Since their attentional capacity is low, they cannot focus on two things simultaneously. Studying the extent to which they can understand real objects and virtual information is required. In addition, preparing for accidents that may occur while they focus on the screen should be considered in designing VR applications.

Designers should consider how to overcome older adults' physical and cognitive barriers and how to support a stable, comfortable experience for them while they use VR and AR systems. To ensure they do not lose attention and to sustain their engagement with the system, it is important to design the system for controllability, such that they have control and feel as though they are in control. Often, VR requires a level of technical intervention to either set up the application or use it. Therefore, caregivers or family members should be able to use any application to support older adults in its use or adoption.

5.2. Challenges and Design Issues for Social Wellbeing

The quality of life of an individual is increasingly influenced by connections with other people. Sustaining enhanced connections is an important feature in relation to the acceptance of technology [29,58]. For this reason, several technologies and robotics have been developed to enhance communication between elderly people and their families, relatives, friends, nurses, and doctors and support social interaction. However, VR and AR technologies have not been often used for encouraging older adults to engage in social activities. A sense of burden regarding using VR, a technology with which they are unfamiliar, could make them more passive in adopting it, and therefore, they could be reluctant to use VR, such that they cannot participate in social interactions in a virtual environment. In this case, because the technology is designed to promote social interaction of older adults, they can experience a sense of alienation instead. It is necessary to make an effort to offer experiences similar to that in an actual environment through comparison of emotions that older adults experience while interacting with characters in a virtual environment with emotions they experience in real-world relationships.

Older adults will be engaged and become more active when they feel they are involved with a specific activity or human relationship while using the system. A collaborative experience will encourage them to solve difficult problems together and reduce their fear of using the system. Such experiences will play an important role in changing the stereotype that they find it difficult to understand instructions for using modern technologies.

5.3. Challenges and Design Issues for Psychological Wellbeing

Although AR and VR are designed to support an independent lifestyle for older adults, subsidiary problems, such as issues regarding setup and software updates, still make them dependent. They will be reluctant to use the system because of such inconvenience, instead of preferring to use it for the benefits they would gain. It is necessary to consider how the installation process can be simplified so that older adults can use it by themselves. It is important to develop a variety of content, but it is also crucial to offer an environment in which they can use such systems by themselves.

Many studies on AR have focused on old adults with disability. Most previous studies on interactions among old adults have defined an elderly individual using the criterion of age or inability. Age is not a predictor for use of interactive technology. It is a fact that physical ability decreases as one becomes old. Older adults are usually overlooked when developing new systems. It is necessary to recognize the fact that older adults, too, have various preferences and needs and to understand their characteristics. Each elderly person has a different level of skills and capability. VR and AR technologies can be designed to tailor these to the individual's cognitive level and mobility issues. VR and AR can satisfy older adults' needs autonomously by recognizing and inferring their behavioral patterns and can make decisions for the users when appropriate. When this design principle is applied, it is possible to reduce fear, difficulty, and stress that they feel while they use new technology. In addition, it is possible to help them understand the properties and functions of the system and to correct the improper use caused by their incorrect understanding. For example, a VR system can customize virtual reality experiences to reconnect older adults to life. The system can collect and store the patterns of interaction for individuals, reduce their memory load, and reduce their frustration or anxiety about their confidence, effectiveness, and ability to utilize new technology. Such a system supports interaction according to individuals' different abilities in different ways.

Providing opportunities to be creative can draw the attention of older adults. Creativity can be encouraged in various ways, providing interesting experiences with games, music, dance, performance, drawing, and art in the form of opportunities for expression and challenges. Arts and crafts and other creative projects can help alleviate boredom and keep seniors' minds busy, and may even help prevent feelings of depression. Further, arts and crafts help with hand–eye coordination, cognitive abilities, and concentration. Once users overcome the challenges presented at one stage, they can be rewarded and provided new resources that allow them to try more complex challenges with higher rewards. A system that is designed in this way can instill confidence in older adults who use it and may be able to increase the likelihood that they view technology positively. Much software for VR and AR can be designed to support creative activities for older adults.

6. Conclusions

Technologies such as AR and VR have been highlighted as a solution used to resolve problems of older adults who face various challenges in their later part of life. The main goal of these emerging technologies is to facilitate care for them, to monitor and support their health. Social and emotional wellbeing have also recently been recognized as an important factor for enhancing their quality of life. However, there is a lack of AR and VR technologies for supporting their social and emotional wellbeing. New technologies that have been designed without understanding the characteristics of older adults impede their experiences with these technologies or even cause harm to vulnerable users. How can they use technologies, by incorporating them into their daily lifestyle? To answer this question, we proposed the critical evaluation framework in this study, focusing on three categories: physical, social, and psychological wellbeing. This paper has a limitation in providing a quantitative estimate of studies on AR and VR technologies for older adults published until now. It should be noted that it is difficult for this study to address an integrated, synthesized overview of the current state of AR and VR technology for older adults since it is not a systematic review through meta-analysis. However, this study proposes significant insights, existing gaps, and future research directions for studies of AR and VR through a critical assessment of the selected papers. We identified challenges and barriers that older adults experience in using AR and VR applications. Further, we identified design issues that need to be considered to overcome challenges and gain benefits from such applications. The framework proposed in the present study can be utilized as design principles to consider in AR and VR designs to promote wellness for older adults. The design in which these design principles have been considered properly can: (1) provide a comfortable experience in the use of AR and VR technologies; (2) promote social interaction or social connectedness; and (3) also induce positive and pleasant experiences. In addition, after the development of AR and VR technologies, our proposed framework can be used as an evaluation tool to judge the success of such technologies. Insights generated from this study would be the basis for future designs of AR and VR applications for older adults.

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