Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 196 (2022) 426–433

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies 2021

Using Virtual Reality in the Development of an Index-Engine of Physical and Emotional Sustainability

Carlos R. Cunha [a,b,*], Alcina Nunes [a,b], Paula O. Fernandes [a,b], José Bragada [a,b], Luís Pires [a,b], Maria José [c,b], Pedro Magalhães [a,b]

[a] *Applied Management Research Unit (UNIAG), Portugal*
[b] *Instituto Politécnico de Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal*
[c] *Mountain Research Center (CIMO), Portugal*

Abstract

Nowadays, there is a growing need for rehabilitation associated with demographic changes and health trends, with an increase in the prevalence of non-communicable diseases and an aging population. Although well-being is classically associated with a set of physical activities, the reality of today's society often shows that there is a lack of time available to develop activities that promote well-being. This fact is aggravated in aging populations by less mobility and greater isolation. In this domain, information and communication technologies have greatly contributed to helping healthcare providers to develop new understanding, measurement and action strategies that promote the physical and emotional well-being of their patients. Accordingly, the role of Virtual Reality has been shown to be promising for the generation of well-being. This article, as part of a broader funding project, reviews the state of the art of the role that Virtual Reality has played in the promotion of well-being, being an exercise of conceptualization that converges in the proposal of a conceptual model - an Index-Engine of Physical and Emotional Sustainability, which will be prototyped and field tested in the future.

* Corresponding author. Tel.: +351 300 029 903.
E-mail address: crc@ipb.pt

10.1016/j.procs.2021.12.032

Keywords: Virtual Reality; Machine Learning; Model; Emotional Sustainability; Well-being; Health

1. Introduction

The demographic change in several industrialized countries has proved to be a challenge for societies, both economically and socially. Current R&D efforts show that information and communication technologies can successfully contribute to improving all dimensions of the quality of life of populations, especially their older fringe. With regard to human health and well-being, these are a complex and multidimensional phenomenon that needs to be understood in a holistic way [1].

As populations age, it becomes increasingly important to promote "Active Aging" lifestyles, as aging will tend to result in greater frailty that will influence the physiological state of an individual, making it the most vulnerable, dependent and less well-being [2]. In this domain, the role of Information and Communication Technologies (ICT) has been important and, specifically, Virtual Reality (VR). According to [3], the impact of emotion regulation interventions on physical and mental well-being has been widely documented in the literature, although the use of VR is an approach only found in recent years, in clinical and non-clinical settings.

The COVID-19 pandemic situation currently plaguing the world, has forced very significant changes in most of our daily lives. In this new reality, people had to adapt their work and leisure routines. Accordingly, the use of VR can have a positive impact on the physical and mental well-being of users, as a way to overcome existing restrictions [4]. The stress of daily routines combined with the lack of time that negatively impact people's well-being can be alleviated through the use of VR sessions, often applied in short periods of time. According to [5], using VR to provide an immersive VR experience can positively influence an individual's mood, well-being, and future thinking.

Recent state of the art demonstrates that there has been a growing interest in mindfulness applications to empirical wellness research and in the use of VR environments as a tool for mindfulness training [6]. The use of VR can contribute to multiple well-being scenarios, including the treatment of phobias. In [7], VR techniques and bio-monitoring of individuals are combined to understand emotional responses in phobia scenarios, allowing monitoring and adjustment and thus a better understanding of panic factors.

Although VR is often used in a static way - with predefined scenarios that individuals experience, our view is that approaches with immersive VR environments, along with the constant monitoring of different biological parameters of individuals, can be improved through the use of Machine Learning (ML) and its ability to analyze data and create models that allow the identification and prediction of scenarios that lead to a customization of VR scenarios for each session and each individual, as well as real-time adjustments in the immersive experiences of VR This approach will tend to be richer in the quality and effectiveness of applied therapies.

The remainder of this paper is organized as follows: after a characterization of modern societies and, specifically, the aging and isolation of a significant fringe of populations, reviews the role that VR has had and could play in creating solutions capable of monitoring, evaluating and shaping the emotional state and people's well-being. To fulfill this desideratum, a conceptual model based on immersive VR, monitoring of biological parameters and ML is proposed. This work is an ongoing effort that is in the initial prototyping phase and whose test results will be used to validate the proposed model.

2. Topics on Demographic Characterization

Demographic trends are showing that, currently, due to medical and technological advances, due to better living conditions, and due to a change in the mortality and fertility pattern, Europe has an aging population. The projections indicate that the proportion of the population with 80 years or more is growing faster than other age segments [8] [9]. This is called the demographic aging and is registered all over Europe.

Many countries are already preparing and developing public policies in order to restrain the impact of this phenomenon, since it is expected that an extra pressure will be placed on the public health care and welfare systems

[9]. Some policies are focusing on keeping the elders living among their community instead of taking them into institutions, such as nursing homes [8]. The fact that they live in their community and not institutionalized on the long run can enhance the probability of a sustainable care system and especially can maintain the elders' quality of life [8]. However, the changes in their families' way of life are leaving more and more elders alone and sometimes even isolated due to the characteristics of the region where they live. In fact, the elders sometime are alone, with no close support by their family, friends or neighbors. The reduction of their social network is a reality that comes with aging, enhanced with the distance from other relatives, and all combine can increase the perception of loneliness and isolation.

Furthermore, studies show that those elders that live alone have the highest poverty rates. Also, those elders that live alone are often more associated with the rural regions [10]. These facts can explain a more reluctant option from the elders to actively participate in events, health appointments and, thus, increasing their isolation. This social isolation greatly increases the deterioration of health indicators and to a decrease of their well-being and quality of life, since both depend on existing social relationships [11]. Along with that, factors that occurs during the old age like the predisposition to some diseases and cognitive and physical disabilities, can also reduce life quality and well-being. However, there is a growing concern about how to live with life quality and mental well-being [12].

Specifically, in this COVID-19 pandemic, it was noted that the elder populations located in rural areas, with lower access to health care was more at risk and suffered more due to their isolation. In fact, COVID-19 brought an extraordinary risk to the social and mental well-being of the older people since it demanded social distancing and with that increased the loneliness and isolation [13].

Although there are several ways to virtually connect with other people and services, the fact is that the elders are less prone to use online technology, especially in the segment of 80 years or more and also the ones with lower incomes [13].

In this context, ICT can help maintain or increase rural elders' well-being and be a way to overcome the isolation they have, either social or geographical. In future years, where more focused policies related to health and aging care will be developed, the ICT will play a major role in helping elder people stay healthy and live independently in their own homes, connecting them to services, socializing or getting support, no matter how isolated or lagging regions they live in [14], [15].

Improving ICT-based solutions capable of helping people in the diagnosis and treatment of physical and emotional problems is an urgent desire. In particular solutions that can reach people from the fringe of the most fragile and isolated population.

3. Context and Application of Virtual Reality in Human Health and Well-being

The promotion of well-being is classically associated with a set of real physical experiences. However, there are several constraints that can make it impossible to enjoy these experiences. In this context, there are several population groups where these setbacks are manifested: elderly populations typically have lower mobility rates and, in more rural regions, greater isolation and lack of support. Contingent situations such as the current pandemic situation (i.e. COVID-19) have made it almost impossible to fully enjoy outdoor spaces, as well as to carry out leisure activities. Also, various common health problems can disable people from engaging in activities that typically provide physical and mental well-being. Finally, the more hectic life that has characterized the last decades, where stress and lack of time predominate, have greatly contributed to the emergence of physical and mental well-being problems. To contribute to solving these problems, technology has played a key role and in this context, the potential of VR has been widely studied in the bibliography.

The technology associated with digital content has been revolutionizing the health area, affecting the way we provide and access care and, in this context, VR can allow the assessment of cognitions, emotions and behaviors [16]. According to [17], VR is a potentially revolutionary tool for psychological interventions and has been used in immersive therapies in mental disorders, with the potential to make psychiatric treatments better, more cost-effective and more easily available to larger groups of patients. According to [18], relaxation has significant restorative properties and implications for public health and, in this context, VR experiences where pleasant virtual environments predominate, which enhance calm down, seem to promote states of relaxation; given how little time people tend to have to relax, it can be a very significant approach.

In the field of health and well-being, applied to multiple different scenarios, VR has been used in a number of conceptual and applied research. VR, combined with mobile phones, has been used in the treatment of generalized anxiety disorders [19]. In [20], an investigation is presented on the ability of VR to positively influence the physical and emotional mood of pediatric cancer patients, as well as to understand which factors influence the effectiveness of VR, in this domain. Self-administered VR environments has used for stress reduction and relaxation in teens home study, in the context of the COVID-19 pandemic [21].

The VR contribute to emotional and social well-being has also been studied in older adults in assisted living communities, having concluding that VR applications revels potential for improving the quality of life among the aging population [22]. In a study applied on university students, with in traumatic and stressful life event history and symptoms of posttraumatic stress disorder, showed that the VR applications can produced greater positive affect and satisfaction and perceived credibility [23].

In the field of tourism, the values of VR perceived by tourists result in their satisfaction and it was found that tourists' subjective well-being is improved due to their satisfaction with VR tourism [24]. In [25], VR was used in a training program for promoting and improve subjective well-being through interactive feedback.

In the domain of the elderly population, in [26], VR was focused to their ability to virtualize representations of nature in order to promote the well-being of the elderly, who often have mobility restrictions along with the multiple health care measures that affect their ability to go out home and appreciate the nature. Also in the context of the elderly population, VR was also applied for stimulation, improvement and cognitive assessment; with the results showing positive effects in the dimensions of general cognition, executive functioning, attention and visual memory [27]. In [28], is study the use of a immersive and non-immersive VR approaches to explore the emotional impacts of viewing 360° videos, on elderly populations and young people, referring the importance of positive emotions for the physical and mental health of elderly. According to [29], with the world population aging rapidly, VR can play an important role in maintaining and improving the quality of life of the elderly, as well as in filling several gaps related to the provision of health care and the fact that sometimes caregivers are few in number and difficult to access.

The review of the state of the art reveals the importance of the role that VR has and will continue to play in promoting people's mental and physical health and well-being. However, there is still a vast field of study in the development of more integrated models where VR will co-exist. Furthermore, it is vital to promote the creation of an index and its mechanisms capable of measuring physical and emotional sustainability and, in this way, making the results of each of the approaches measurable and objective. Accordingly, in the next chapter, a conceptual model is presented, where VR in cooperation with other technologies, such as ML, conceptualize the development of a well-being index-engine based on the ability to measure the well-being generated by the use of technologies capable of, in theory, induce physical and emotional well-being.

4. Proposed Conceptual Model

The model presented in Figure 1, represents a conceptualization of a system capable of measuring the emotional state of individuals, as well as promoting their improvement, through therapeutic sessions based on VR.

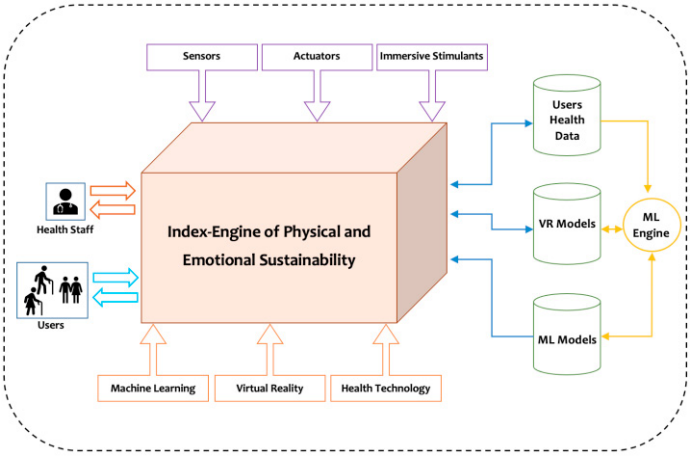

Fig. 1. Conceptual Model

This model is based on three basic premises: (a) VR sessions are capable of measuring emotional states and, when customized for the patient, they can influence their emotional state and, as such, their well-being. (b) A VR session must be a customized process either at its starting point and/or in real time, depending on the patient's biological parameters measured during the session - it is therefore a continuous process of adjustment. (c) The use of medical data from a wide range of patients (in addition to the patient himself) may contribute to the creation of VR models suitable for supporting customized therapies; thus, ML techniques are used to define initial VR session models, as well as generate real-time optimizations in the session and in future sessions. ML approaches to model individuals well-being, and its drivers, were used in several studies related to well-being, wellness and mental health in general [30]–[33]

The proposed model is based on the use of VR to provide virtual sessions, in a controlled environment and in a home environment, to measure the emotional state and well-being of individuals, as well as to provide therapeutic sessions capable of contributing to the improvement of said emotional states and general well-being. To achieve this goal, the central engine of this model - Index-Engine of Physical and Emotional Sustainability (IEPES) - uses three sources of information:

(a) The health data repository: which contains information about the different patients (i.e. all information on various biological parameters measured over time).
(b) The VR model repository: which contains several models of VR sessions for different therapeutic scenarios, as well as a whole set of useful objects for customizing these scenarios.
(c) The ML repository: which contains ML models capable of identifying stress and well-being scenarios and, in this way, understanding, managing and customizing VR sessions.

In this domain, the ML process is fed by the existing information about the different patients and thus able to create adequate ML models that allowed managing the VR model repository.

The IEPES system is supported by two layers of technology. In one of the layers are the main technologies that enable the proposed approach - VR (e.g. VR glasses), ML and medical technology (e.g. blood pressure, oxygen levels, etc.) capable of measuring different key biological parameters to feed the system with information that will allow real-time decision making and conclusions at each end of a VR session.

On the other layer, there is a set of technologies capable of making VR sessions more immersive (typical VR glasses are limited in their ability to provide deep immersiveness). As such, a set of sensors and actuators can co-exist with the technologies mentioned above in the previous layer. Specifically, “immersive stimulants” technologies stand out, which will play an important role in the creation of immersiveness due to the ability to produce emotional sensations (e.g. ambient smell sprays).

From the point of view of IEPES users, patients will be able to experience VR sessions in a controlled environment (i.e. consulting room) and in their homes (sessions previously prescribed and resulting from the system's recommendations). Regarding the health staff, they will be able to define which VR models should be used by patients, as well as obtain reports with all the information collected during the VR sessions that patients participated and, in this way, understand the emotional and well-being of their patients and the way they are responding to the VR therapeutic sessions – with all the contribution that these reports can give to the definition of strategies to improve the well-being of their patients. This vision supports the creation and automation of an index of well-being and emotional sustainability, capable of measure and score the well-being of a given individual, and its evolution over time.

In order to briefly explain the features that translate part of the system's functioning, Figure 2 presents a use case diagram. The healthcare staff will be able to define VR models suitable for the patient. Likewise, you will be able to consult the patient's health data and the reports provided by the system that will allow you to prescribe customized VR sessions.

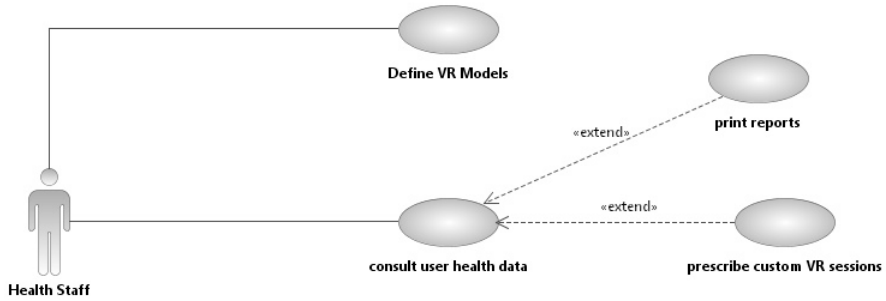

Fig. 2. Use Case Diagram – Health Staff

Figure 3 shows the use case diagram that represents the functionalities linked to the user (i.e. patient) of the system. The user will be able to experience standard and/or customized VR sessions. The customization process is originated by the use of ML templates and the application of custom VR templates. In this process, historical health data (i.e. resulting from the various sessions carried out) are used, which will contribute to the referred customization. In all VR experiments the measured biological parameters are monitored.

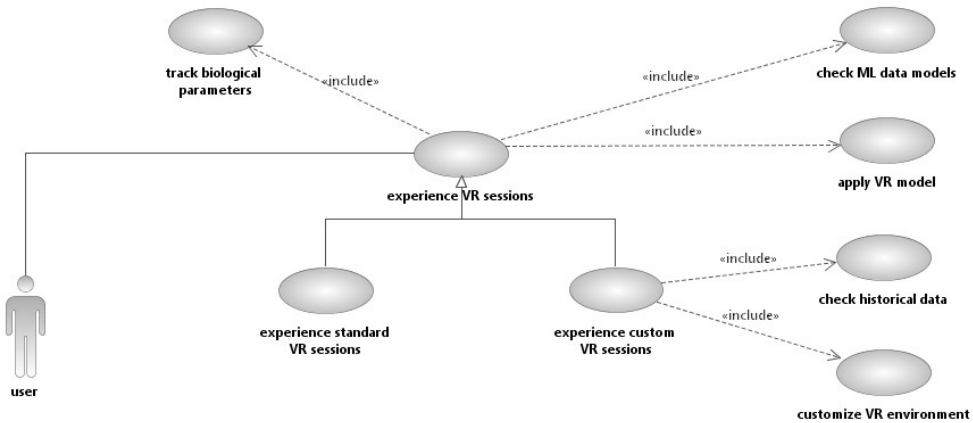

Fig. 3. Use Case Diagram – User

The proposed model represents an effort to conceptualize an approach based on VR with ML integration in order to contribute to the creation of a system capable of measuring the well-being of individuals and thus improving, through VR sessions, the emotional state of these individuals.

5. Conclusion

Technology has been part of the evolution of responses in the area of healthcare and caregivers. Although, initially, technology has focused its usefulness on the creation of mechanisms for the diagnosis and treatment of physical illnesses, in recent decades there has been a greater focus on diagnostic and treatment solutions for illnesses associated with emotional conditions and well-being.

This work focuses on the potential of VR and how it can be used to measure and manage the emotional state of individuals, contributing to the creation of therapies that promote well-being. To this end, a conceptual model was presented that combines the use of VR, monitoring mechanisms of biological parameters and the use of ML to create dynamic VR sessions. In this way, the model presents itself as a contribution to the use of ICT in the area of health and well-being that has proved to be of growing importance in recent decades and that, given the daily lives in which populations live, human longevity and the current lifestyle is of considerable importance. The work presented is currently in an initial prototyping phase that will help to validate the model and its potential.

Acknowledgments

This article is a result of the project “GreenHealth - Digital strategies in biological assets to improve well-being and promote green health” (Norte-01-0145-FEDER-000042), supported by Norte Portugal Regional Operational Programme (NORTE 2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund (ERDF)

UNIAG, R&D unit funded by the FCT – Portuguese Foundation for the Development of Science and Technology, Ministry of Science, Technology and Higher Education. UIDB/04752/2020

References

[1] A. Hedman, N. Karvonen, J. Hallberg, and J. Merilahti, “Designing ICT for Health and Well-being BT - Ambient Assisted Living and Daily Activities,” 2014, pp. 244–251.

[2] A. Peternier *et al.*, “Chloe@University: an indoor, mobile mixed reality guidance system. BT - Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST 2007, Newport Beach, California, USA, November 5-7, 2007.” pp. 227–228, 2007.

[3] J. I. Montana *et al.*, “The Benefits of emotion Regulation Interventions in Virtual Reality for the Improvement of Well-being in Adults and Older Adults: A Systematic Review,” *J. Clin. Med.*, vol. 9, no. 2, 2020.

[4] A. Siani and S. A. Marley, “Impact of the recreational use of virtual reality on physical and mental well-being during the Covid-19 lockdown,” *Health Technol. (Berl).*, vol. 11, no. 2, pp. 425–435, 2021.

[5] S. Habak, J. Bennett, A. Davies, M. Davies, H. Christensen, and K. M. Boydell, “Edge of the Present: A Virtual Reality Tool to Cultivate Future Thinking, Positive Mood and Well-being,” *International Journal of Environmental Research and Public Health* , vol. 18, no. 1. 2021.

[6] C. Yildirim and T. O’Grady, “The Efficacy of a Virtual Reality-Based Mindfulness Intervention,” in *2020 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*, 2020, pp. 158–165.

[7] A. Trappey, C. V Trappey, C.-M. Chang, R. R. T. Kuo, A. P. C. Lin, and C. H. Nieh, “Virtual Reality Exposure Therapy for Driving Phobia Disorder: System Design and Development,” *Applied Sciences* , vol. 10, no. 14. 2020.

[8] K. England and N. Azzopardi-Muscat, “{D}emographic trends and public health in {E}urope,” *Eur J Public Heal.*, vol. 27, no. suppl_4, pp. 9–13, 2017.

[9] P. Vanleerberghe, N. De Witte, C. Claes, R. L. Schalock, and D. Verté, “The quality of life of older people aging in place: a literature review,” *Qual. Life Res.*, vol. 26, no. 11, pp. 2899–2907, 2017.

[10] J. E. M. Power, C. Hannigan, S. Carney, and B. A. Lawlor, “Exploring the meaning of loneliness among socially isolated older adults in rural Ireland: a qualitative investigation,” *Qual. Res. Psychol.*, vol. 14, no. 4, pp. 394–414, 2017.

[11] R. M. Gyasi, A. A. Yeboah, C. M. Mensah, R. Ouedraogo, and E. A. Addae, “Neighborhood, social isolation and mental health outcome among older people in Ghana,” *J. Affect. Disord.*, vol. 259, pp. 154–163, 2019.

[12] H. Jafaripoor *et al.*, “The Elders’ Spiritual Well-Being and Their Quality of Life: A Cross-Sectional Study,” *J. Client-Centered Nurs. Care*, vol. 4, no. 3, 2018.

[13] C. Henning-Smith, “The Unique Impact of COVID-19 on Older Adults in Rural Areas,” *J. Aging Soc. Policy*, vol. 32, no. 4–5, pp. 396–402, Jul. 2020.

[14] T. Berg, R. Winterton, M. Petersen, and J. Warburton, "'Although we're isolated, we're not really isolated': The value of information and communication technology for older people in rural Australia," *Australas. J. Ageing*, vol. 36, no. 4, pp. 313–317, 2017.

[15] C. Siegel and T. E. Dorner, "Information technologies for active and assisted living—Influences to the quality of life of an ageing society," *Int. J. Med. Inform.*, vol. 100, pp. 32–45, 2017.

[16] L. R. Valmaggia, L. Latif, M. J. Kempton, and M. Rus-Calafell, "Virtual reality in the psychological treatment for mental health problems: An systematic review of recent evidence," *Psychiatry Res.*, vol. 236, pp. 189–195, 2016.

[17] C. N. W. Geraets, E. C. D. van der Stouwe, R. Pot-Kolder, and W. Veling, "Advances in immersive virtual reality interventions for mental disorders: A new reality?," *Curr. Opin. Psychol.*, vol. 41, pp. 40–45, 2021.

[18] S. Riches, L. Azevedo, L. Bird, S. Pisani, and L. Valmaggia, "Virtual reality relaxation for the general population: a systematic review," *Soc. Psychiatry Psychiatr. Epidemiol.*, 2021.

[19] C. Repetto, A. Gaggioli, F. Pallavicini, P. Cipresso, S. Raspelli, and G. Riva, "Virtual reality and mobile phones in the treatment of generalized anxiety disorders: a phase-2 clinical trial," *Pers. Ubiquitous Comput.*, vol. 17, no. 2, pp. 253–260, 2013.

[20] M. Tennant, G. J. Youssef, J. McGillivray, T.-J. Clark, L. McMillan, and M. C. McCarthy, "Exploring the use of Immersive Virtual Reality to enhance Psychological Well-Being in Pediatric Oncology: A pilot randomized controlled trial," *Eur. J. Oncol. Nurs.*, vol. 48, p. 101804, 2020.

[21] J. Sonney, E. A. Björling, S. Rodriguez, and N. Carr, "Pivoting to 'No Contact': A Protocol for Conducting a Virtual Reality Relaxation Home Study for Teens Amidst the COVID-19 Pandemic," *J. Pediatr. Heal. Care*, 2021.

[22] C. X. Lin, C. Lee, D. Lally, and J. F. Coughlin, "Impact of Virtual Reality (VR) Experience on Older Adults' Well-Being BT - Human Aspects of IT for the Aged Population. Applications in Health, Assistance, and Entertainment," 2018, pp. 89–100.

[23] P. Frewen *et al.*, "Proof of Concept of an Eclectic, Integrative Therapeutic Approach to Mental Health and Well-Being Through Virtual Reality Technology," *Front. Psychol.*, vol. 11, p. 858, 2020.

[24] Y. Li, H. Song, and R. Guo, "A Study on the Causal Process of Virtual Reality Tourism and Its Attributes in Terms of Their Effects on Subjective Well-Being during COVID-19," *Int. J. Environ. Res. Public Health*, vol. 18, no. 3, 2021.

[25] J. Kim *et al.*, "Development and Validation of a Virtual Reality-Based Training Program for Promoting Subjective Well-Being," *PSYCHIATRY Investig.*, vol. 17, no. 12, pp. 1207–1215, Dec. 2020.

[26] J. Van Houwelingen-Snippe, S. Ben Allouch, and T. J. L. Van Rompay, "Virtual Reality Representations of Nature to Improve Well-Being amongst Older Adults: a Rapid Review," *J. Technol. Behav. Sci.*, 2021.

[27] P. Gamito, J. Oliveira, C. Alves, N. Santos, C. Coelho, and R. Brito, "Virtual Reality-Based Cognitive Stimulation to Improve Cognitive Functioning in Community Elderly: A Controlled Study," *Cyberpsychology, Behav. Soc. Netw.*, vol. 23, no. 3, pp. 150–156, Feb. 2020.

[28] Q. Liu, Y. Wang, M. Z. Yao, Q. Tang, and Y. Yang, "The Effects of Viewing an Uplifting 360-Degree Video on Emotional Well-Being Among Elderly Adults and College Students Under Immersive Virtual Reality and Smartphone Conditions," *Cyberpsychology, Behav. Soc. Netw.*, vol. 23, no. 3, pp. 157–164, Nov. 2019.

[29] B. K. Wiederhold, "How Virtual Reality Is Changing the Reality of Aging," *Cyberpsychology, Behav. Soc. Netw.*, vol. 23, no. 3, pp. 141–142, Mar. 2020.

[30] T. Kyriazos, M. Galanakis, E. Karakasidou, and A. Stalikas, "Early COVID-19 quarantine: A machine learning approach to model what differentiated the top 25% well-being scorers," *Pers. Individ. Dif.*, vol. 181, p. 110980, 2021.

[31] C. A. Makridis, D. Y. Zhao, C. A. Bejan, and G. Alterovitz, "Leveraging machine learning to characterize the role of socio-economic determinants on physical health and well-being among veterans," *Comput. Biol. Med.*, vol. 133, p. 104354, 2021.

[32] J. Tohka and M. van Gils, "Evaluation of machine learning algorithms for health and wellness applications: A tutorial," *Comput. Biol. Med.*, vol. 132, p. 104324, 2021.

[33] B. J. H. Yarborough and S. P. Stumbo, "Patient perspectives on acceptability of, and implementation preferences for, use of electronic health records and machine learning to identify suicide risk," *Gen. Hosp. Psychiatry*, vol. 70, pp. 31–37, 2021.