02 Simple VR for better living

Telma Mota, Altice Labs
Telma@alticelabs.com

Fausto de Carvalho, Altice Labs
CFausto@alticelabs.com

Hugo Paredes, UTAD & INESC TEC
hparedes@utad.pt

Leonel Morgado, Universidade Aberta & INESC TEC
Leonel.Morgado@uab.pt

Physical and cognitive rehabilitation based on natural interaction and VR has been on our horizon for several years, and we have been conducting experimentation towards that goal through several exploratory research initiatives.
This article addresses some aspects of the state-of-the-art of VR in healthcare and well-being, with opportunities in the domain of rehabilitation based on natural interaction and VR being analyzed and put in perspective with the SmartAL ecosystem roadmap.

Keywords

VR; SmartAL; eHealth; Rehabilitation; Exergames; Cognitive games; Assisted living; Active aging; pHealth

Introduction

The early adoption of novel, cutting-edge technology is usually led by youngsters. Yet, studies, research, and trials around cheaper and more accessible virtual and mixed reality allow us to clearly identify significant opportunities associated with elderly users, who keenly embrace games and applications for physical and cognitive rehabilitation, fighting social isolation and loneliness by enhancing socialization, and active and healthy aging.

This article addresses some aspects of the state-of-the-art of virtual reality (VR) in healthcare and well-being, analyzing opportunities in the domain of rehabilitation based on natural interaction and VR, considering the SmartAL ecosystem roadmap.

Furthermore, the exploratory project "VReAbility" being carried on by UTAD/UAb/INESC TEC and Altice Labs is presented, focusing on functional requirements and scenario constraints for affordable deployments.

VR (et al.) for healthcare

In recent years, several studies and projects have demonstrated promising results using video games to address well-being aspects such as increased physical activity and mobility, better socialization and positivity, improved cognitive functioning, and attenuated deterioration with normal aging or in the context of rehabilitation and specific neurodegenerative conditions [1]. Several successful apps are available in the market to allow ad hoc regular cognitive workouts or tracking fitness activity while competing with friends, matching their achievements and progress. Exergames are video games that are also a form of exercise, relying on technology that tracks body movement or reaction. They have been around for more than two decades, going back to "Dance Dance Revolution" (**Figure 1**, **left**), one of the first major successes in the area, which sold over three million copies when ported from the original arcade to PlayStation console in 1998. The popularity of the Nintendo exergames hardware Wii Fit (**Figure 1**, **right**) led to it start being successfully used in multiple hospital "Wiihab" scenarios, such as post-stroke rehabilitation programs and Parkison's disease therapies [2].

Technology has been advancing quickly, with more powerful, affordable, and lightweight devices and, likewise, the potential of applying extended reality (XR) to clinical procedures for wide populations increasing significantly. Researchers have been exploring the potential of using motion capture and VR to address musculoskeletal impairments due to multiple disorders and diseases, or aging [4]. Furthermore, VR is quite promising in the area of physical rehabilitation because it presents patients with an immersive approach. This approach leverages challenges and narratives for context and entertaining to accomplish the precise goals of tedious treatments and protocols addressing aspects such as postural stability and joint mobility, e.g., after surgical procedures, often with the flexibility and comfort of being performed remotely, at home [5]. Recent reviews of VR rehabilitation systems provide evidence of patient enjoyment and willingness to participate in care plans that incorporate VR [6]. Along with the natural interaction based on motion capture, the embodiment is a key aspect of VR efficacy for such applications because it makes the user feel as actually being part of the screen: the avatar, which is the graphical representation of the user, becomes a natural extension of its human body, and the virtual interaction is perceived as real, thus more engaging [7].

Traumatic brain injury (TBI) is a clinical condition that causes attention, memory, affectivity, behavior, planning, and executive dysfunctions, with a significant impact on the quality of life of the patient and family. Cognitive and motor rehabilitation programs are essential for the clinical recovery of TBI patients, improving

FIGURE 1 – Dance Dance Revolution (left) (AP Photo/Robert F. Bukaty) and Nintendo Wii Fit at the 2009 Gaming World Moscow event (right) [3]

functional outcomes and the quality of life. Various researches have shown that VR has the potential to provide an effective assessment and rehabilitation tool for the treatment of cognitive and behavioral impairment on TBI patients during the different phases of their rehabilitation, creating a positive, motivating, and enjoyable learning experience [8]. VR and augmented reality (AR) are also being used with success in mental healthcare, addressing conditions such as addictions, phobias, and post-traumatic stress disorders, using exposure therapies based on immersive serious gaming and physiological computing (e.g., electroencephalogram headbands).

Many combinations of VR/AR/XR technologies [9] are already common in e-Health and active aging current practices, involving a variety of devices, such as console peripherals, head-mounted displays, wearables, cameras, and sensors, used in multiple scenarios for informal well-being as well as for formal therapies.

SmartAL - smart assisted living

The need to encourage cognitive and physical activity, empowering people by providing autonomy to conduct their daily activities with minimum external help, yet with confidence by the nearness of professionals and family, led Altice Labs to introduce SmartAL, a telemonitoring and teleconsultation environment where patients, relatives, and caregivers may follow the status of a user/senior in real-time, keeping track of daily health and well-being tasks, using a web, tablet, smartphone, or TV interface [10].

As discussed in the previous section, regular ad hoc use of affordable exergames or fitness apps is effective for staying active. Still, it falls short whenever it involves particular healthcare conditions, which require professional guidance or monitoring the adherence to rehabilitation plans, traditionally associated with lengthy, expensive programs and dedicated facilities. SmartAL approach may be used to extend those plans and professional tracking to the comfort and flexibility of patients staying home (**Figure 2**).

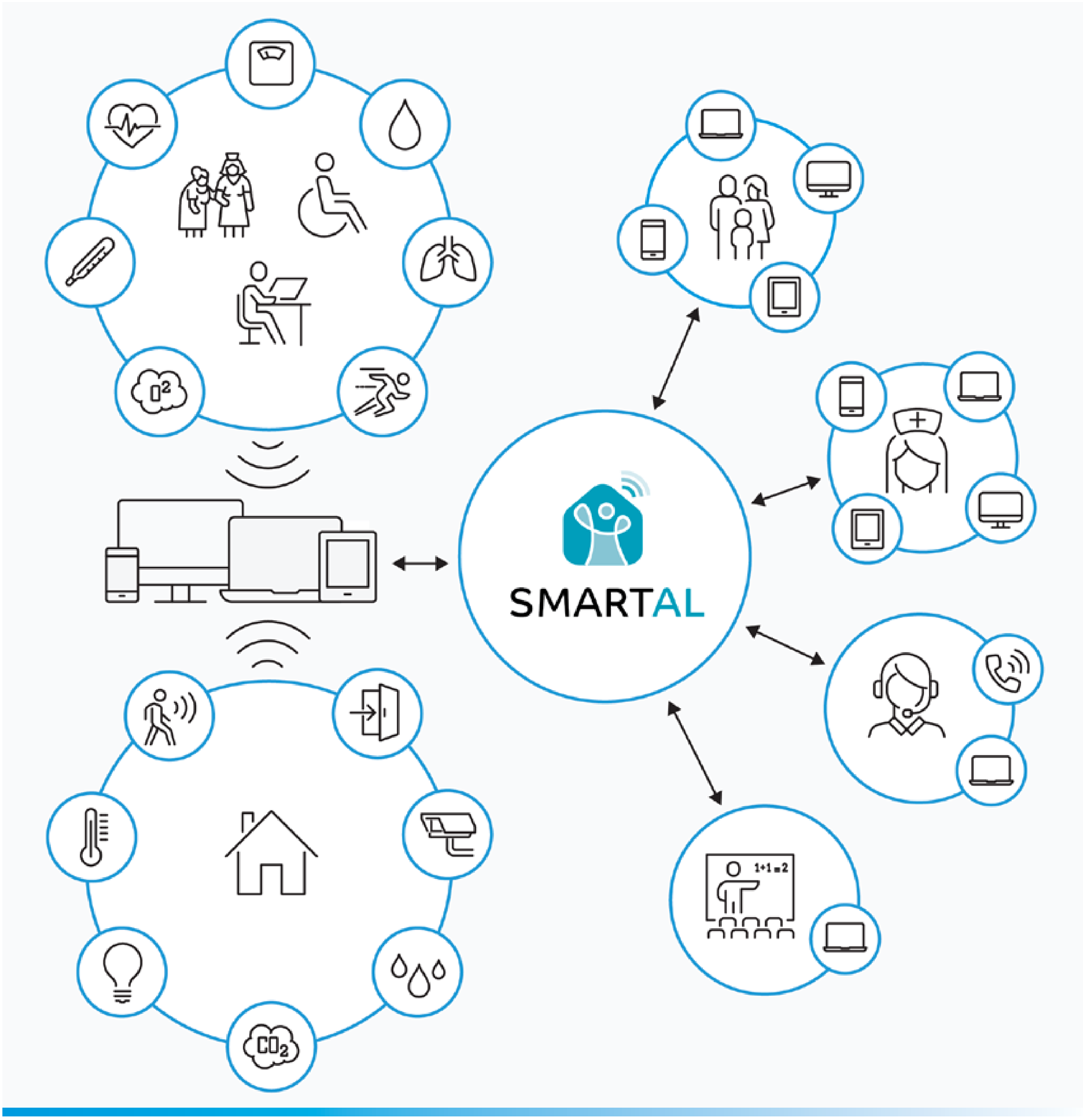

FIGURE 2 – SmartAL ecosystem

The core functionality of SmartAL consists of collecting information from clinical (e.g., oximeter, thermometer) and non-clinical devices (e.g., personal band, smartwatches) and depicting it to the user. The collected values are matched against thresholds previously configured by healthcare professionals and, when beyond limits, notifications may be sent to both patients and caregivers. Besides telemonitoring of vital signs and teleconsultation, SmartAL also allows simple or medical questionnaires to assess the patient's well-being status, and videos to assist the user in the clinical equipment use or to provide guidance and coaching.

This set of tools provides the necessary services to older people and empowers them with the autonomy to deal with their e-Health activities without the need for constant assistance at home or countless visits in person to the health units. In this context, the key concept for conducting and supporting patients' daily life is the task. Caregivers may schedule tasks and plans (i.e., groups of tasks) may be scheduled by caregivers to keep track of the users' daily activities. There are predefined types of tasks such as "collect clinical measurements", "take medication", or "perform a teleconsultation". There is also an open type that allows professionals to add new activities on the fly (e.g., "take a five-minute walk", "drink a glass of water every hour"). After defining a task, it is possible to associate it with one or more patients and personalize it by specifying the schedule and who should be notified of the task accomplishment.

Bridging the gap: VReAbility

Physical and cognitive rehabilitation based on natural interaction and VR has been on our horizon for several years, and we have been conducting experimentation towards that goal through several exploratory research initiatives. With projects such as Online Gym, Move4Health, InMerse, and ARani, we teamed with academia to test concepts and technological aspects, validating the use of low-cost devices for multi-user shared VR-based rehabilitation purposes [11][12]. Furthermore, in the context of the submission of UpperCare and VR2Care proposals to H2020 calls, a panel of specialists with solid expertise on various aspects of the ecosystem was brought together, and we had the opportunity to reach important insights on how to advance the state-of-the-art in this domain, and address our target market [13].

Our vision of bringing VR for physical/cognitive rehabilitation and active aging to the SmartAL roadmap is centered on the need to keep the current operational model in place by creating additional engagement incentives and integrating those functionalities with the already existing mechanisms. This integration would allow personal progress feedback and professional coaching, supervision, and monitoring of adherence to prescribed VR-based tasks and plans, as well as the possibility of automating the platform generation of notifications when certain conditions are met or inferred. Moreover, we are aiming for a very simple and low-cost approach without the need for sophisticated equipment, avoiding driving users and customers away due to increased cost and complexity. Besides the typical one-to-one patient-therapist or the lonely patient-app scenarios, we also want to achieve an architecture open to multi-user shared VR, addressing the important socialization aspects of active aging.

In the scope of ongoing R&D activities for progressing SmartAL, in 2020, we started VReAbility exploratory project with INESC TEC, involving researchers from UTAD and UAb, with the objective of building a prototype to test novel options for motion capture and natural interaction, as well as an architecture for rehabilitation scenarios based on simple VR.

Nowadays, it makes sense to place most of the processing in the cloud. Besides keeping the user-end simple and cheaper, which is an important requirement for this type of service, it also provides easier lifecycle management, including the flexibility of incremental features, for example, the future addition of coaching and monitoring

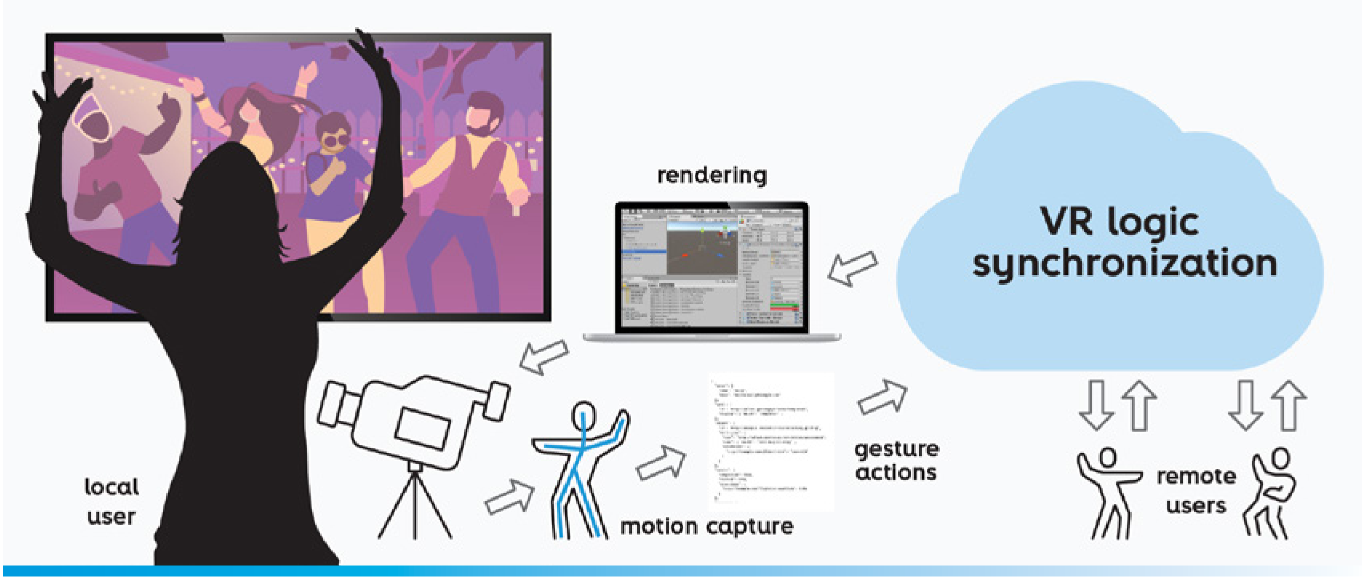

FIGURE 3 – VReAbility functional architecture

based on AI. Moreover, a multi-user scenario requires motion capture streams from multiple users to be mixed, in a single central place, into a common synchronized VR scene.

State-of-the-art software libraries are currently widely available to allow real-time tracking of body keypoints and pose estimation with moderate computational requirements. As so, we used a regular wide-angle webcam instead of relying on specific devices to take care of motion capture (e.g., Microsoft Kinect), as we did in previous projects. This camera option matches the need of having a peripheral to anchor the required functionality at the user target scenario: a small computer (e.g., Raspberry Pi) placed near the TV, hosting the motion capture camera, and feeding the TV with the live VR scene arriving from cloud processing. **Figure 3** depicts VReAbility functional architecture.

After researching and experimenting with several approaches and libraries, VReAbility created a prototype system including the following modules, aligned with the presented architecture:

- Motion capture – whole-body 3D poses are continually estimated, based on OpenPose [14] detection of user body, hands, and facial skeleton keypoints on images captured by the webcam;
- Gestures and actions – the raw stream of poses is matched against a set of rules and processed to recognize relevant gestures that are organized into an experience API (xAPI) [15] sequence of user actions and queued upstream;
- VR logic – the application scenario is a set of VR scenes based on the Unity game engine [16], with an avatar mirroring the user poses. The detected actions are mapped into the scene/game interaction logic so that the user may attempt to achieve the proposed challenges and goals by moving in front of the webcam. Multi-user functionality can be addressed by having a different avatar for each user, with their movement queued as distinct xAPI streams, combined and synchronized into a common VR scene presented to everyone;
- Rendering – the interactive VR scene is shown to the user as a live (TV) video feed. This functionality may be cloud-based, e.g., if computational resources on the target device are limited.

A simple single-user cognitive exergame was developed to test the initial prototype system and explore several aspects of the integration with SmartAL. “Battle Motion Chef” is a multi-level progressive cooking challenge. The player must move sideways and raise the arm to pick the correct ingredients among the random falling ones and place them inside the pot to complete each recipe (**Figure 4**). This game, and other similar ones, may be considered VR hyper-casual games, a very appealing concept currently only applied to mobile applications [17].

What's next?

Current health services provisioning is mostly acute illness driven. Still, the focus is adjusting towards the management of chronic diseases, preventive healthcare through a healthy lifestyle and extended independent living promotion, prompted by major factors such as population aging and the digital transformation. This requires a completely new approach for health organizations, placing the patient in the center, developing a continuous process, and shifting the care from a hospital-driven approach to a home-driven or, more generally, a pervasive approach. In this context, the wide adoption of new low-cost and patient-adaptive technologies for remote patient management enables trustful, transparent, and not much intrusive monitoring, harnessing effective pHealth solutions – personal, personalized, predictive, preventive, pervasive, and participatory.

Cognitive and physical rehabilitation based on VR exergames is just a fraction of the broad potential of emerging XR and AI technologies applied to the shifting paradigms of healthcare. Although we know we have just scratched the surface, we firmly believe that we are unlocking a powerful ecosystem around SmartAL that can play a significant role in our aging society. Patients, relatives, and caregivers will be provided with an adequate and balanced set of VR tools to support particular rehabilitation needs and to prevent their occurrence through regular monitored activity to maintain and improve physical and cognitive capabilities, for a better assisted life.

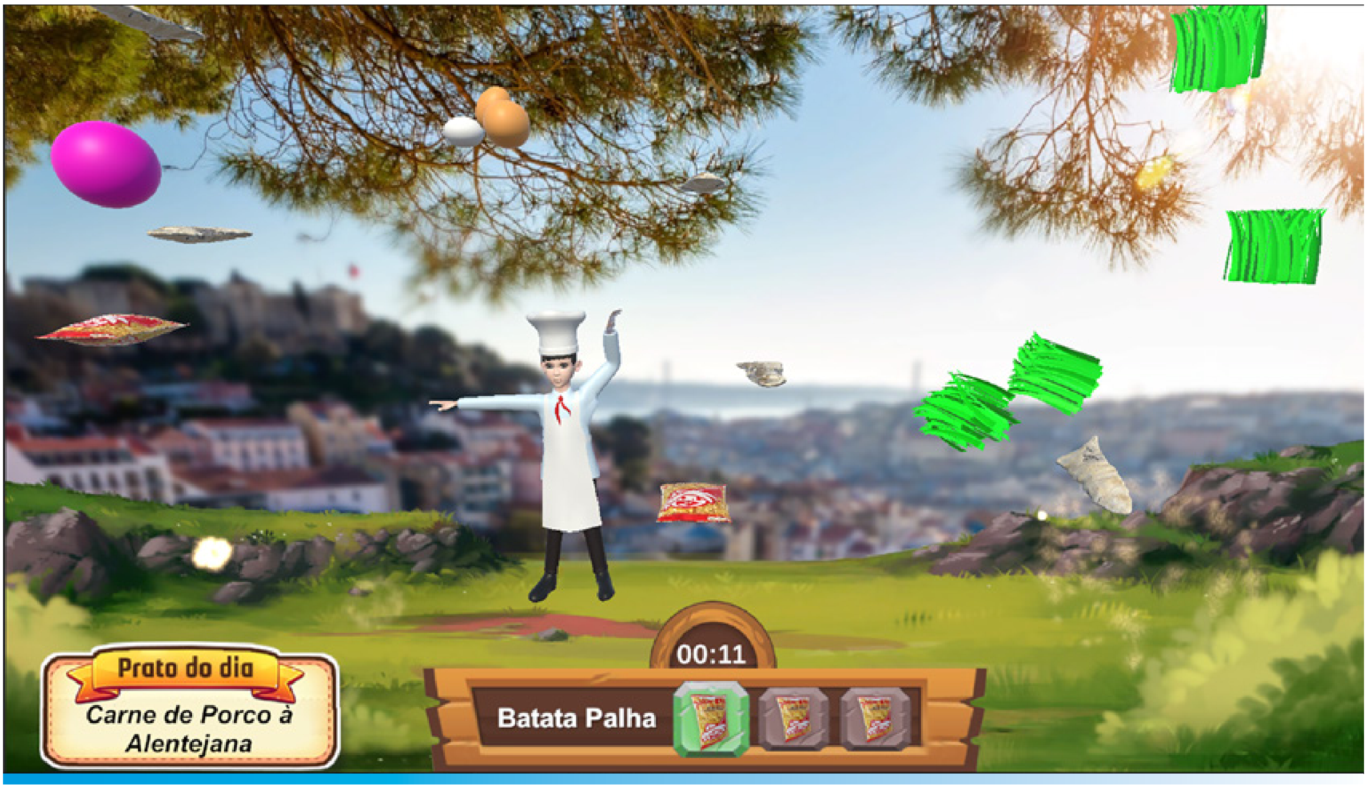

FIGURE 4 – VReAbility game prototype: Battle Motion Chef

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References

[1] F. L. Vázquez, P. Otero, J. A. García-Casal, V. Blanco, Á. J. Torres, and M. Arrojo, "Efficacy of video game-based interventions for active aging. A systematic literature review and meta-analysis," *PLoS One*, vol. 13, no. 12, p. e0208192, Dec. 2018, doi: 10.1371/journal.pone.0208192

[2] N. B. Herz, S. H. Mehta, K. D. Sethi, P. Jackson, P. Hall, and J. C. Morgan, "Nintendo Wii rehabilitation ('Wii-hab') provides benefits in Parkinson's disease," *Parkinsonism Relat. Disord.*, vol. 19, no. 11, pp. 1039–1042, Nov. 2013, doi: 10.1016/j.parkreldis.2013.07.014

[3] Wikimedia Commons, "File:Wii Fit girl at Igromir 2009 (4082095322).jpg --- Wikimedia Commons{,} the free media repository." 2020. [Online]. Available: https://commons.wikimedia.org/w/index.php?title=File:Wii_Fit_girl_at_Igromir_2009_(4082095322).jpg&oldid=472904329

[4] F. Cassola, L. Morgado, F. de Carvalho, H. Paredes, B. Fonseca, and P. Martins, "Online-Gym: A 3D Virtual Gymnasium Using Kinect Interaction," *Procedia Technol.*, vol. 13, no. December, pp. 130–138, 2014, doi: 10.1016/j.protcy.2014.02.017

[5] T. Rose, C. S. Nam, and K. B. Chen, "Immersion of virtual reality for rehabilitation - Review," *Appl. Ergon.*, vol. 69, pp. 153–161, May 2018, doi: 10.1016/j.apergo.2018.01.009

[6] G. Tao, B. Garrett, T. Taverner, E. Cordingley, and C. Sun, "Immersive virtual reality health games: a narrative review of game design," *J. Neuroeng. Rehabil.*, vol. 18, no. 1, p. 31, Dec. 2021, doi: 10.1186/s12984-020-00801-3

[7] K. Kilteni, R. Groten, and M. Slater, "The Sense of Embodiment in Virtual Reality," *Presence Teleoperators Virtual Environ.*, vol. 21, no. 4, pp. 373–387, Nov. 2012, doi: 10.1162/PRES_a_00124

[8] M. G. Maggio *et al.*, "Cognitive rehabilitation in patients with traumatic brain injury: A narrative review on the emerging use of virtual reality," *J. Clin. Neurosci.*, vol. 61, pp. 1–4, Mar. 2019, doi: 10.1016/j.jocn.2018.12.020

[9] D. Beck, L. Morgado, and P. Shea, "Finding the Gaps about Uses of Immersive Learning Environments: A Survey of Surveys," *JUCS - J. Univers. Comput. Sci.*, vol. 26, no. 8, pp. 1043–1073, Aug. 2020, doi: 10.3897/jucs.2020.055

[10] Altice Labs, "SmartAL: Smart Assisted Living," *Altice Labs*, 2020. https://www.alticelabs.com/site/smartal/

[11] F. de Carvalho, V. Orvalho, and L. Morgado, "Motion capture: aplicações e-health e wellbeing," *Saber & Fazer*, pp. 270–275, 2014, [Online]. Available: http://hdl.handle.net/10400.2/4438

[12] F. de Carvalho and H. Paredes, "HCI boosted by AI," *InnovAction*, vol. 4, pp. 100–109, 2019, [Online]. Available: https://www.alticelabs.com/site/innovaction

[13] H. Paredes *et al.*, "UPPERCARE: A community aware environment for post-surgical musculoskeletal recovery of elderly patients," in *2017 IEEE 21st International Conference on Computer Supported Cooperative Work in Design (CSCWD)*, Apr. 2017, pp. 251–256. doi: 10.1109/CSCWD.2017.8066703

[14] G. Hidalgo *et al.*, "OpenPose," 2021. https://github.com/CMU-Perceptual-Computing-Lab/openpose

[15] Rustici Software, "xAPI.com," 2021. https://xapi.com/

[16] Unity Technologies, "Unity," 2021. https://unity.com/

[17] Adjust and Unity, "Hyper casual gaming in 2020," *Adjust*, 2020, [Online]. Available: https://www.adjust.com/resources/downloads/hyper-casual-report-2020/?download=%2Fresources%2Fdownloads%2Fhyper-casual-report-2020