The convergence of Virtual Reality and Personalized medicine

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***Abstract*— This paper aims to reflect the synergy between Virtual Reality (VR) and personalized medicine by showcasing recent advancements in VR-based solutions across various medical contexts and conditions. Furthermore, Artificial Intelligence (AI) plays a vital complementary role within VR solutions, enhancing their effectiveness and personalization. By harnessing AI's data analysis, VR treatments can be adjusted to individual patient's needs. This work introduces an innovative VR-based system designed to improve social skills and abilities for individuals with autism spectrum disorders (ASD). The architecture presented here entails immersive scenarios adapted to individual profiles and customizable environments. The convergence of VR and personalized medicine holds transformative potential; thus, this research represent a pioneering application in the field of autism therapy.**

Keywords—Personalized Medicine, Virtual Reality, ASD, therapy, treatment, profiling.

I. Introduction

Artificial intelligence (AI) has emerged as the cutting-edge technology of today, establishing itself as a vast and ever-expanding field. Robots and intelligent systems have played an important role in automating human operations and effectively resolving a wide range of complicated problems. As a crucial domain, medicine can benefit from AI technologies. It has the potential to enhance and improve patient care. In recent years, the notion of treating medicine has shifted from conventional or classical medicine, which tries to provide universal remedies, to a new concept of Personalized Medicine (PM). However, AI has contributed to the prediction of disease risks, the proposal of targeted treatments, and the assistance of particular patient in real time. In this context, Chatbots have used several types of patient data to provide personalized assistance by communicating with patients and supporting them. Furthermore, AI applications should focus on psychological illnesses, like autism, to improve social and communication skills and integration[1].

Exploring AI have revealed a research motivation that leads to discover another potential power, the immersive domain of technology: Virtual Reality (VR).

In recent year, PM, artificial intelligence (AI) and virtual/augmented/mixed reality (VR/AR/MR) have been considered as transformative tools in healthcare domain and technology.

II. Context and Problem Statement

A. General context

Personalization is a concept that revolves around customizing experiences, services, or information to align with an individual's needs, characteristics, choices, or preferences. Recent developments have significantly broadened its potential across various domains, enabling the creation of bespoke encounters for each person. However, the central notion remains that personalization involves conferring benefits based on individual preferences, choices, experiences, characteristics, or behaviors. While there isn't a singular definition that fully encapsulates this concept, several terms are commonly used interchangeably with personalization, notably "customization" or "precision." The interpretations and applications of personalization are diverse, yet its fundamental objective remains consistent: refining experiences and services to better suit each person's specific requirements, preferences, and traits.

The ultimate goal of customization, whether in the context of e-commerce, healthcare, education, and beyond, is to heighten customer/user satisfaction and engagement. This is achieved by providing information, products, or services that deeply resonate on an individualized level. To illustrate, consider marketing or e-commerce, where technological solutions have emerged to offer customized recommendations for users based on their purchase history or browsing data. In the realm of education, e-learning platforms and MOOCs provide meticulously tailored learning courses and materials that harmonize with individual strengths and areas for improvement.

Additionally, personalization is used in the field of medicine, known as "Personalized Medicine" or "Precision Medicine." This approach focuses on care tailored to each patient, considering their unique traits during treatment.

The fundamental idea of PM is to ensure that the right patient receives the suitable treatment [2].

Then, precision medicine research aims to increase our understanding of treatment effectiveness by using insights gathered from individuals' unique characteristics to predict and improve patient outcomes [3]. Additionally, AI approaches need multimodal data that includes variables related to physiology, genetics, lifestyle, and environmental aspects. [4]

Moreover, artificial intelligence (AI) is progressively being incorporated into the field of medical science, resulting in significant advantages, including extensive reach, affordability, heightened effectiveness, mobility, diverse applications, and enhanced service output. AI techniques are employed in areas such as disease detection, prognostication, robotic surgery, image analysis, virtual medical support, pharmaceutical exploration, and healthcare administration. The utilization of AI in the healthcare sector impacts multiple facets and encompasses diverse applications, as outlined in the diagram below (Figure 1).

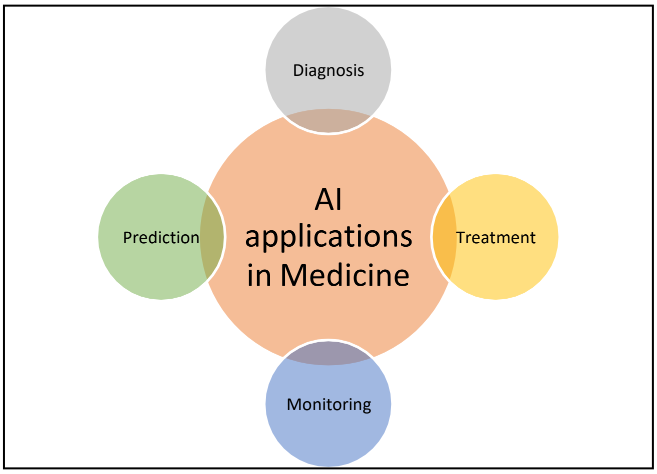

Figure 1: AI integration in Medicine field

The application of AI in PM goes beyond diagnosis and prediction. VR technology, for example, enable immersive and interactive worlds that may be adapted to the specific needs of each patient. This opens up new possibilities for delivering tailored therapies, particularly to enhance critical care medical practices for patients, families and healthcare professionals [6].

At the same time, the convergence of AI and PM gives the opportunity to previously inaccessible information on patient conditions and responses to interventions. However, there remains an unexplored area at the intersection of these fields, where the immersive capabilities of VR/AR/MR could potentially revolutionize therapeutic approaches, particularly for conditions such as autism.

B. *Problem statement*

PM considers a diverse range of patient data, including genetic information, crucial biomarkers, treatment records, environmental influences, behavioral preferences, and medical imaging results… As the use of AI algorithms is powerful in term ofenhancing patient outcomes, decreasing healthcare cost, and proposing a customized medical service according toindividual's needs by analyzing its data patterns.

As AI is on the way toward revolutionizing personalized medical services, VR is another ground-breaking technology that emerges to improve patient experiences and treatment efficacy. The AI-driven treatments approaches even if they are personalized, they cannot assure patient's engagement and don't consider the emotional state of the patient.

However, VR technology creates a new dimension of personalization that goes beyond data processing and information analysis to providing an immersive personalized experiences for patients.

Both AI and VR contribute, to improve personalized healthcare outcomes. But how can we profit from their combined strengths to achieve the ultimate goal?

Recognizing the attention given to AI's role in PM, this paper shifts its focus to discover the potential of VR in this context. So, we will reveal how VR experiences can be harnessed to create a tailored experience that improves treatment outcomes. And, the complex problem is how to profit from VR potential as an extended part of the bridge founded by AI for PM.

III. Related Works

VR has emerged as a challenge technology in PM, combining immersive VR experiences with AI insights to improve treatment paths, enrich patient experiences, and personalize healthcare approaches based on individual patient data. The convergence of PM and AI has garnered a significant interest within the research community. Researchers have investigated a variety of AI techniques for using patient data for improved treatment outcomes. This section highlights the recent works that proposed VR-based solutions to administer personalized treatments to patients. These studies confirmed the capacity of VR as a revolutionary method that has an impactful healthcare result. Those solutions are across a diverse range of personalized treatment for addiction, a therapy, a therapeutic and relaxation interventions, and exercise programs.
The authors in [7] created an immersive VR experience using an iPhone X and a Google Cardboard device. They repurposed a virtual airport environment, adapting it to teach air travel skills to autistic young adults. In other study [8], VR solution has contributed on developing a single-user VR scenario that is able to capture automatically nonverbal data. The solution can classify, using a ML model (LSTM), nonverbal behavior patterns in autism and typically developed individuals. It boasts high accuracy, sensitivity, and specificity.

Apart from its implications for autism, the proposed VR system can be employed for other disorders. Its potential to optimize the diagnostic process, minimize costs and reduce time, while ensuring an objective assessment, underscores its value across medical applications.

Another notable instance lies in motor rehabilitation [9], where VR exer-games address motivational and psychological challenges in gesture training. By adapting exercises based on emotion recognition, a VR-PEER adaptive exer-game system demonstrates its potential in improving motor rehabilitation outcomes. This convergence showcases the broader applicability of VR for PM across various contexts. Moreover, as we cited before, AI has a complementary role where emotional data can be interpreted through ML or DL models.

Another study [11] that found promising results in reducing blood sugar and serum fructosamine levels using VREPs for treating type 2 diabetes. Participants immersed in VR exercise sessions using IoT-equipped indoor bicycles and VR headsets, experiencing increased muscle mass and greater exercise immersion. This highlights the importance of individualized VR-based therapies in medical settings and the benefits of personalized VR interventions in health management.

Let us move to investigate into the possibilities of immersive virtual reality (IVR) in the context of personalized interventions. According to [12], people with mild to borderline intellectual disabilities (MBID) and alcohol use disorders (AUD) require specialized alcohol refusal training. The study used the Persuasive System Design (PSD) methodology to create an IVR-based alcohol refusal training with professionals in addiction treatment. The virtual atmosphere, convincing interactions with virtual people, and persuasive discourse were painstakingly created through a series of focus groups. The outcome is a simulation of peer pressure that offers suggestions for tailoring IVR interventions for people with MBID and AUD.

Other use of VR was employed also for mental health treatment. In [13], authors present VRelax as a personalized VR relaxation therapy that utilizes semantic ontologies and online learning to create individualized calming virtual environments. This innovation showcases VR's potential to revolutionize stress-related mental illness treatment by offering scalable and personalized solutions without the need for constant professional presence.
VR's applications have extended beyond mental health and relaxation, finding innovative use in post-stroke rehabilitation, exemplified by the Gait-Triggered Mixed Reality (GTMR) approach explored in [14]. The goal is to address the difficulties of post-stroke rehabilitation, as annually, brain strokes affect millions of people, and GTMR provides a promised cognitive-motor therapy specifically designed for lower-limb rehabilitation.
The study highlights the potential of GTMR for enhancing walking cadence and eliciting brain responses by examining gait and EEG data from stroke patients.
In order to help children with ADHD in developing better attention skills, this study presents a novel game concept that blends gaze control and VR. The study [15] creates an enjoyable training game for these kids by making games engaging, utilizing gaze control, and including VR immersion. This strategy is described in the paper's abstract, along with how it seeks to improve attention in children with ADHD.
In [10], the utilization of a Chatbot is presented as an additional innovative solution for individuals with autism and mental health concerns. This approach provides personalized support for detecting disorders, for conditions management, and enhancing social integration.

Researchers have shown significant interest in proposing VR solutions for individuals with autism, known as Autism Spectrum Disorders (ASD). It's a type of neurodevelopmental disorders characterized by difficulties with social communication and the presence of repetitive behavior patterns and interests [6].

Table 1: Summary of cited VR solutions

Article Reference	Objective	Data used	Personalization aspect	Architecture	Result
[7]	Use virtual reality (VR) for teaching young adultswith autism in air travel skills.	Evaluate participants' attentiveness, language function, activity comprehension, and observe their interactions with the technology through clinical observations.	Personalize teaching airtravel skills to meet the needs of individuals on ASD	VR	The study showed the promise of VR technology by using it toteach autistic young people airtravel abilities and demonstrated the potential of VR technology to develop a lifeskills and facilitate the transition into adulthood for individuals on the autism spectrum.
[8]	Develop a system for screening ASD using VR social interactions, specifically simulating a shopping experience with an embodied agent.	Behavioral responses, body movements (head, gaze, eye…)	The ML model used for classification uses as inputan individual data collected from VR system	VR	Applying LSTM for classification resulted in impressive accuracy, with a 100% accuracy rate, a sensitivity of 83.0%, and specificities of 99.1% and 98.9% across all features for both matched and random datasets.
[9]	a personalized and adaptive Virtual Reality exer-game (serious gamein general) VR-PEER based on emotion recognition.	Emotional data	The game content is adapted on the emotionalstate of the user.	VR, ERP (DeepFace Framework)	The system achieved an accuracy rate of 97.45%. Consequently, the solution can adapt the exercise game based on the patient's emotions, enhancing the overall user experience.
[10]	Implement VR for immersive exercise experiences using a head-mounted display, connecting an IoT sensor to an indoor bicycle and a smartphone.	Collected from scratch	Considering health state of each patient	VR, IoT	Patients with diabetes who followed a two-week VREP program observed a reduction in MBG, an increase in musclemass, and an improvement in exercise immersion.

[11]	Develop an immersive virtual reality (IVR) solution enabling realistic practice of alcohol refusal.	Filled-in digital and paper-based templates	Study the behavior of eachpatient in a peer pressure situation.	VR	As an initial simulation, the proposed system is realistic and interactable as the patients are able to interact and response
[12]	Propose an architectural framework for a virtual reality environment designed for relaxation therapy for individuals coping with mental health issues.	Personality data, Anxietydata	With the use of ontologies,this approach can model user's preferences and provide ana adapted experiences.	VR	Proposed VR solution offers a scalability and there is no need forreal-time professionals.
[13]	Introduce a mixed reality system triggered by gait, aimed at assisting post-stroke patients with lower limb rehabilitation. Evaluate its effectiveness in use with stroke patients who are able to walk.	EEG signals, knee AROM, Cadence	The program gives participants immediate visual input about their walking gait to help with lower-limb stroke therapy.	Mixed Reality, EEGsystem	Results show that measures for cadence and knee performance have improved. The benefits of such interventions for lower- limb stroke recovery are highlighted by AROM, which emphasizes the significance of proper task difficulty.
[14]	Introduce a novel video game concept utilizing VR technology and gaze control to enhance focus and attention development in children diagnosed with ADHD.	Gaze behavior	The solution is a single-user game and it train eachchild to improve its attention.	VR	The architecture proposed in the VR-based game has the potential to be a promising method for aiding children withADHD in their therapy.
[15]	InViRS is an advanced virtual reality (VR) platform allowing children with ASD engage in activities promoting the development of gaze sharing and following skills.	Gaze data	The solution provide an adaptive controller and real-time tracking features	VR	InViRS's capacity to track varied game data configurations, adapt difficultylevels, and offer real-time interaction and feedback.

IV. VR-based system for Autists: The proposed archietcture

This section highlights an innovative architectural concept designed exclusively to satisfy the demands of autistic people. The system shown here is a dynamic combination of cutting-edge VR technology and artificial intelligence (AI) capabilities, drawing inspiration from existing VR-based tailored therapy solutions. Its primary goal is to precisely adapt responses to the particular demands of autistic children, successfully addressing the gaps that currently exist in traditional therapy approaches. Examining its intricacies reveals that this groundbreaking paradigm not only affects the way we think about therapy, but it also broadens the horizons of what is conceivable in terms of treatment possibilities, opening up a whole new universe of possibility.

A. *Diverse Objectives of Personalized Treatments and Therapies*

It is necessary to review the context of the existing tailored therapy solutions in order to put into perspective the proposed VR-based personalized autism therapy system. Below, we provide an overview of some non-VR therapeutic techniques, each of which is geared to target certain areas. These solutions include a wide range of topics, including behavior management and communication skills, as well as emotional expression and sensory processing:

- **Rehabilitation**
- **Relaxation and stress reduction**
- **Social skills development for autists**
- **Healthy Lifestyle recommendations**
- **targeted mental health interventions**
- **Chronic diseases assistance**

B. *Design of the solution*

In the continuously evolving field of personalized therapeutic therapies, a game-changing proposition emerges: a VR-based system designed specifically to meet the unique needs of children with autism. This part reveals an architectural system that combines cutting-edge technology with personalized care, ushering in a new era of autistic kid therapy.

In addition, this innovative solution demonstrates the potential synergy between VR technology and individualized treatment. The idea is to of the system is precision-based, beginning with a profiling module that diagnoses persons with autism based on observations, therapist input, and parental insights. This classification serves as the foundation for all subsequent therapy efforts, adjusting dynamically as each child progresses.

Every module inside this architecture encompasses a different aspect of this transformative solution, highlighting the necessity of personalized experiences.

Starting from the central element of "**Profiling**", which aims to understand each of the complex personalities that cover the spectrum, to the dynamic potential of "**Individual Instantaneous Measures**", which captures real-time insights related to the emotional state of the patient.

This component is designed to create an environment that resonates with the needs of every autistic individual. It's here where the "**Adapter environment**" reacts and suggest a VR content according to the child's profile. In parallel, the immersive **'VR Personalized Simulation'** component curates a therapeutic experience, evolving based on the child's profiling data and real-time measures. This personalized therapy consists of a **'Chatbot Interface**' to ensure the assistance and the support for the autist, and it's from where the system gather the sentiment analysis insights. Moving now to another crucial module "**Evaluation system**" that gives therapists the ability to produce thorough reports after a VR simulation, analyzing the session's effects on the child. This step helps to make sure that every steps of the child's experience continues to be a powerful way for good change.
Finally, the **"Patient database**" is the orchestral component of the whole system where the patient data. It ensures the availability of health patient information.

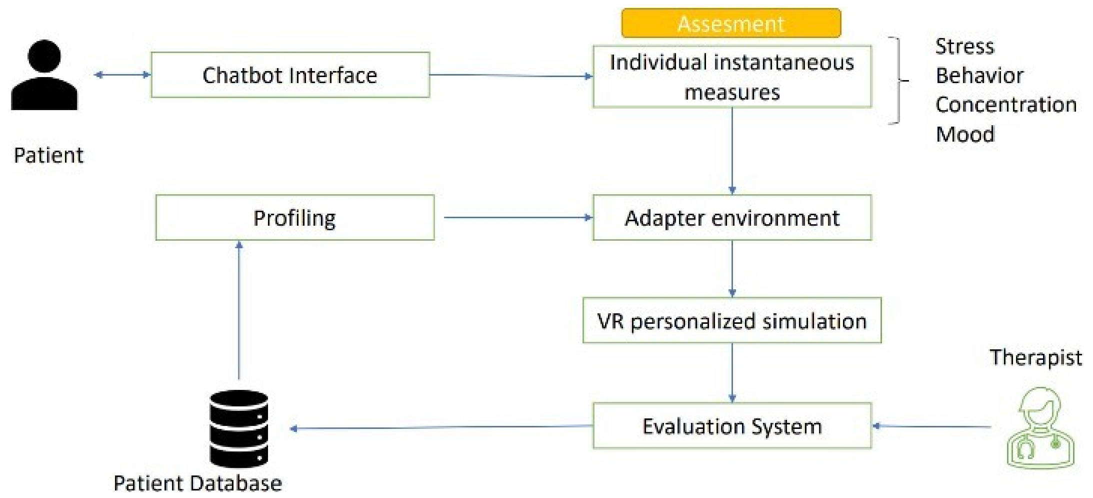

Figure 2: VR-based system for personalized medicine

We will summarize the key elements of each part of our suggested VR-based personalized therapeutic system. Each component has its goal and reason to be part of the proposed architecture.

- **Profiling**: consists of classifying ASD children based on observations and reports from the therapist. To learn more about their personality traits, speaking with their parents in an interview will be beneficial. Additionally, clinical questionnaires are useful for assessing behaviors,communication issues, and life skills. When an advancement (behavior, development skills,) is noted by the professionals, a re-profiling may be required.
- **Individual instantaneous measures**:measurements or observations related to an individual, it could provide the emotional situationof the patient.
- **Adapter environment**: An intelligent component of the VR system, it switches automatically to another VR content based on the profiling data.
- **VR personalized simulation**: It comprises VR technology material that will be used on patients as part of the personalized therapy system. It displays a videos, visuals, tasks, or activities contents to thepatients. A personalized topic will be suggested at the first level, and after each session, it will be more customized for each patient based on profiling data and the instantaneous measures.
- **Chatbot Interface**: A crucial component since it helps the patient throughout the VR simulation. Itoffers each person's measurements in an instant T.
- **Patient database**: It contains all patient-related information, including past health information.
- **Evaluation system**: Each VR simulation will be followed by a report from the therapist, who will then assess how it affected the patient.

We have included a chatbot interface to increase interaction between the patient and the system. The idea of integrating a chatbot into a VR environment was greatly influenced by the architecture of an autistic assistance chatbot that was proposed in [16]. Our main attention in this work is the useof a VR environment as a therapeutic session, but through the chatbot interface module we intent to boost the user engagement and personalize the proposed VR session.

CONCLUSION

In conclusion, this study has explored the changing landscape of personalized therapies and treatments, anchored by the potentially game-changing capabilities of VR solutions. The study started out by summarizing recent references that highlighted VR's crucial function in creating tailored solutions, further emphasizing the fundamental importance of Artificial Intelligence (AI) in this paradigm shift. The proposed architecture represents a significant advancement in redefining therapeutic and skill development frameworks since it immerses people on the autistic spectrum in VR experiences that are especially suited to their profiles and health data. Our efforts are focused on improving the fundamental profiling step as we move forward with further developing and expanding this architecture. This study affirms the symbiotic relationship between these endeavors and the continuing discussion regarding tailored medicines.

REFERENCES

[1] F. E. El rhatassi, B. El Ghali, et N. Daoudi, « Improving Health Care Services via Personalized Medicine », in *Proceedings of the 6th International Conference on Big Data and Internet of Things*, M. Lazaar, E. M. En-Naimi, A. Zouhair, M. Al Achhab, et O. Mahboub, Éd., Cham: Springer International Publishing, 2023, p.435-449.

[2] M. Hassan *et al.*, « Innovations in Genomics and Big Data Analytics for Personalized Medicine and Health Care: A Review », *International Journal of Molecular Sciences*, vol. 23, nº 9. MDPI, mai 2022. doi: 10.3390/ijms23094645.

[3] I. Hajirasouliha et O. Elemento, « Precision medicine and artificial intelligence: overview and relevance to reproductive medicine », *Fertility and Sterility*, vol. 114, nₒ 5. Elsevier Inc., p. 908-913, novembre 2020. doi: 10.1016/j.fertnstert.2020.09.156.

[4] A. Silva-Spínola, I. Baldeiras, J. P. Arrais, et I. Santana, « The Road to Personalized Medicine in Alzheimer's Disease: The Use of Artificial Intelligence », *Biomedicines*, vol. 10, nº 2. MDPI, février 2022. doi: 10.3390/biomedicines10020315.

[5] J. Li, J. Huang, L. Zheng, et X. Li, « Application of Artificial Intelligence in Diabetes Education and Management: Present Status and Promising Prospect », *Frontiers in Public Health*, vol.8. Frontiers Media S.A., mai 2020. doi: 10.3389/fpubh.2020.00173.

[6] R. R. Bruno *et al.*, « Virtual and augmented reality in critical care medicine: the patient's, clinician's, and researcher's perspective », *Crit. Care*, vol. 26, nº 1, p. 326, oct. 2022, doi: 10.1186/s13054- 022-04202-x.

[7] I. T. Miller, C. S. Miller, M. D. Wiederhold, et B. K. Wiederhold, « Virtual Reality Air Travel Training Using Apple iPhone X and Google Cardboard: A Feasibility Report with Autistic Adolescents and Adults », *Autism Adulthood*, vol. 2, nº 4, p. 325-333, déc. 2020, doi: 10.1089/aut.2019.0076.

[8] M. Robles *et al.*, « A Virtual Reality Based System for the Screening and Classification of Autism », *IEEE Trans. Vis. Comput. Graph.*, vol. 28, nº 5, p. 2168-2178, mai 2022, doi: 10.1109/TVCG.2022.3150489.

[9] Y. Izountar, S. Benbelkacem, S. Otmane, A. Khababa, M. Masmoudi, et N. Zenati, « VR-PEER: A Personalized Exer-Game Platform Based on Emotion Recognition », *Electronics*, vol. 11, nº 3, p. 455, févr. 2022, doi: 10.3390/electronics11030455.

[10] Y. J. Lee, J. H. Hong, M. H. Hur, et E. Y. Seo, « Effects of Virtual Reality Exercise Program on Blood Glucose, Body Composition, and Exercise Immersion in Patients with Type 2 Diabetes », *Int. J. Environ. Res. Public. Health*, vol. 20, nº 5, mars 2023, doi: 10.3390/ijerph20054178.

[11] S. Langener, J. Kolkmeier, J. VanDerNagel, R. Klaassen, J. Van Manen, et D. Heylen, « Development of an Alcohol Refusal Training in Immersive Virtual Reality for Patients With Mild to Borderline Intellectual Disability and Alcohol Use Disorder: Cocreation With Experts in Addiction Care », *JMIR Form. Res.*, vol. 7, p. e42523, avr. 2023, doi: 10.2196/42523.

[12] J. Heyse, T. D. Jonge, M. Torres Vega, F. D. Backere, et F. De Turck, « A personalized Virtual Reality Experience for Relaxation Therapy », in *2019 Eleventh International Conference on Quality of Multimedia Experience (QoMEX)*, Berlin, Germany: IEEE, juin 2019, p. 1-3. doi: 10.1109/QoMEX.2019.8743335.

[13] L.-W. Ko *et al.*, « Integrated Gait Triggered Mixed Reality and Neurophysiological Monitoring as a Framework for Next-Generation Ambulatory Stroke Rehabilitation », *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 29, p. 2435-2444, 2021, doi: 10.1109/TNSRE.2021.3125946.

[14] L. Graf, L. Scholemann, et M. Masuch, « Designing VR Games with Gaze Control for Directing Attention of Children with ADHD », in *2021 IEEE Conference on Games (CoG)*, Copenhagen, Denmark: IEEE, août 2021, p. 1-5. doi: 10.1109/CoG52621.2021.9619077.

[15] A. Z. Amat, H. Zhao, A. Swanson, A. S. Weitlauf, Z. Warren, et N. Sarkar, « Design of an Interactive Virtual Reality System, InViRS, for Joint Attention Practice in Autistic Children », *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 29, p. 1866-1876, 2021, doi: 10.1109/TNSRE.2021.3108351.