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LETTER TO THE EDITORS

Virtual reality as a neuroaffirmative tool for autistic individuals: progress and limitations

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This is a decisive moment regarding our understanding of mental health care. New technologies have gone from mere complements to essential allies, paving the way for progress previously considered unattainable. It is precisely in this context that autism spectrum disorder has proven to be a rich field for innovation. With its unique social communication skills, deep-seated interests, and repetitive behaviors, autism spectrum disorder demands what technology is beginning to deliver: truly personalized approaches that are sensitive to individual differences. U.S. Centers for Disease Control data, which indicate one diagnosis for every 36 children,[1] make it clear that this goes beyond a scientific opportunity; it is an urgent necessity. We must develop intervention strategies that are not only effective but comprehend the person behind each diagnosis.

Although traditional behavioral interventions maintain their value, they face considerable obstacles regarding large-scale replicability, universal access, and, most importantly, the effective transfer of acquired skills to everyday situations.[2] This limitation opens the door to immersive technologies such as virtual reality (VR), which offers customizable and controlled environments for systematically practicing socioemotional and cognitive skills in a safe context.

The theoretical foundation of VR interventions in autism rests on multiple pillars. The technology masterfully leverages the visuospatial capabilities often overdeveloped in neurodivergent individuals, converting abstract concepts of social interaction into concrete visual representations.[3] This alignment between technological modality and cognitive profile produces what we can call neuro affirmative environments, therapeutic spaces that respect and address atypical neurology. The great advantage of virtual reality scenarios lies in their flexibility. They allow learning trajectories that adapt to the user's pace, presenting challenges that evolve progressively and the freedom to practice as many times as necessary, always within a protected environment where making mistakes is understood as a natural part of the growth process.[4] When we incorporate elements that make the experience more engaging, such as immediate feedback, reward systems, and increasingly complex tasks, patients not only become more engaged in the activities but also discover genuine motivation to continue. This emotional connection with the process is essential for treatment to remain meaningful over time.[5] The most crucial aspect, however, lies in how these tools are created. Building genuinely neuroaffirmative virtual environments requires the participation of neurodivergent people throughout the development cycle. From the initial conceptualization to the final validation phase, their input must be integrated as a central element of the creative process.[6] This collaborative approach is the only way to develop technologies that establish a meaningful dialogue with their life trajectories. The purpose transcends the mere resolution of specific demands; it is an ethical commitment to recognizing and valuing this population's unique ways of experiencing and interacting with the world.

Consistent empirical evidence has shown that VR therapy has a positive impact across multiple dimensions of development. On the cognitive level, recent meta-analyses attest to significant improvements in executive function, mental flexibility, and planning ability after VR interventions.[7] The sensory immersion of these environments promotes sustained attention, resulting in learning gains superior to those achieved with traditional methods. Notable progress has also been observed in acquiring the practical skills essential for autonomy, such as public transportation use, crossing streets safely, and shopping, all developed through progressive virtual simulations.[8] It is important to note, however, that these promising results are interpreted within a context of methodological heterogeneity in VR platforms and intervention protocols, as well as often limited long-term follow-up, which calls for cautious optimism and highlights the need for more standardized research.

While most VR research for autistic individuals has focused on skill acquisition, a new path is emerging in which this technology can promote empathy and understanding in the neurotypical population. A randomized controlled trial by Koniou et al.[6] found that a brief eight-minute simulation, developed in collaboration with autistic individuals to represent their sensory and social challenges in everyday situations, significantly transformed the attitudes, knowledge, and receptiveness of non-autistic participants toward autism. This innovative approach utilizes VR's immersive potential to create an authentic perspective-changing experience, building bridges of understanding where barriers of ignorance had once existed. This ''perspective-taking'' approach harnesses the immersive power of VR to build cognitive empathy, directly targeting stigmatizing attitudes that create social and workplace barriers. Such an application positions virtual reality not only as a therapeutic tool but also as a valuable resource for social inclusion initiatives and awareness campaigns.

Progress in the social domain has been particularly significant. Pioneering research has shown that social cognition training in virtual environments produces measurable improvements in emotional recognition, theory of mind, and social attribution processes.[9] Neuroimaging techniques have revealed a notable increase in the

activation of brain regions associated with social processing, suggesting that observed behavioral improvement is accompanied by neural transformation. The ability to practice social interaction in customizable scenarios, with repetitions and complexity adjusted to each user, creates unique learning opportunities tailored to individual needs. Modern systems provide objective feedback on communicative nuances, such as eye contact duration, appropriate interpersonal distance, and conversational timing, creating formative experiences transferable to the real world.[10] Specialized applications, such as professional interview simulators, have demonstrated remarkable effectiveness in integrating neurodivergent adults into the job market.[11]

VR is also making a highly relevant contribution in the emotional domain. Studies have consistently reported that immersive interventions produce a significant reduction in anxiety symptoms and notable progress in emotional regulation.[12] Gradual exposure to anxiety-provoking situations in controlled environments enables systematic desensitization while strengthening coping strategies applicable to everyday life.[13] Precise calibration of sensory stimuli allows experiences to be tailored to each individual's perceptual framework, progressively building tolerance to potentially overwhelming inputs.[14] This fine-grained customization makes VR a unique tool for therapeutic work involving emotional dimensions.

Despite the transformative potential of VR therapy, substantial challenges remain. Adverse effects such as virtual pleasure, visual fatigue, and initial anxiety are frequently reported, especially among individuals with sensory hypersensitivity.[15] The intrusive nature of headsets and the full sensory experience hinder the meticulous individual adaptations needed to prevent discomfort and overload. The high cost of quality systems restricts accessibility, particularly in resource-limited settings.[8] Furthermore, methodological heterogeneity across studies, with variations in platforms, protocols, and assessment instruments, hinders comparison of the results.[16,17]

For these advances to equitably reach society as a whole, it is essential to develop a line of research specifically dedicated to creating accessible and scalable VR solutions, complemented by simplified training protocols for health care and education professionals. Such a dual approach would be particularly relevant for socioeconomically vulnerable contexts, where operational simplicity and economic sustainability determine the success of practical implementation.[17] The persistent disconnect between technology developers and end users, which often results in products that do not meet real needs, can be resolved through participatory co-creation.[10] The predominance of studies with small sample sizes and limited follow-up leaves significant gaps regarding the sustainability of therapeutic gains.[10] The ethical dimension of these technologies also deserves careful attention. The collection of sensitive user data, ranging from behavioral and performance metrics to potential physiological indicators, raises important questions about privacy, consent, and information security. Establishing clear ethical guidelines and robust data protection protocols is essential to protecting users and building trusting relationships with the neurodivergent community.

Although current evidence confirms VR's potential as a therapeutic tool for autism, consolidating its role in clinical and educational practices requires future research to overcome critical limitations and systematically explore new frontiers.[7,10] Future research should both increase methodological rigor and expand the scope and sophistication of interventions. An immediate and necessary step would be to address the significant methodological heterogeneity in this area of research.[10] Standardizing protocols and measures is a fundamental requirement for valid comparisons between studies and consolidating the robust body of evidence. The development of standardized study reporting guidelines, detailing technical specifications, intervention protocols, and outcome measures, are critical to enabling robust replication, comparison, and meta-analysis.[7] Concurrently, the generalizability and sustainability of gains should be prioritized through longitudinal designs involving prolonged follow-up (e.g., 6 to 12 months) and ecological transfer measures, such as real-world behavioral observations and blinded third-party reports, in addition to self-report instruments.[10]

Beyond refining established therapeutic applications, the field's scope must be strategically expanded. The promising use of VR for awareness and stigma reduction, as demonstrated by Koniou et al.,[6] should be extensively investigated, evaluating the impact of perspective simulation on key populations and comparing their effectiveness with traditional sensitivity training modalities. The field is simultaneously moving toward increasingly sophisticated and personalized systems. A key path, as highlighted by Failla et al.,[18] lies in the convergence of VR and artificial intelligence to create dynamic interventions that transcend predefined and static scenarios.

Artificial intelligence algorithms can monitor the user's performance, physiological state, and behavioral signals in real time, allowing the virtual environment to automatically adjust its level of difficulty, sensory stimuli, and social demands. This continuous feedback system functions as an automated co-therapist, capable of preventing overload by simplifying tasks when detecting signs of anxiety, or intensifying challenges to maintain engagement. Such synergy could lead to a future with truly intelligent and personalized therapeutic experiences that reshape themselves moment by moment in tune with individual needs. Crucially, all of this technological advancement must be guided by an ethical and methodological commitment to co-creation. The implementation of co-design methodologies, with the active participation of neurodivergent individuals in all phases of the development cycle, from scenario design to defining artificial intelligence algorithm parameters, is essential to ensure the relevance, acceptability, and neuroaffirmative nature of interventions. Such a multidimensional agenda, encompassing everything from standardization and accessibility to artificial intelligence and co-creation, could transition from a proof-of-concept phase to evidence-based, robust, equitable, and truly efficacious practice.[7]

In Brazil, pioneering studies have demonstrated VR's potential for autism intervention, although it still faces challenges specific to our context. Braz et al.[19] developed and tested a national VR system for joint attention training, observing significant improvements in shared attention time in Brazilian children with autism spectrum disorder. In parallel, Silva et al.[20] successfully validated a VR task for emotion recognition specifically adapted for Brazilian children, which highlights the importance of developing culturally sensitive instruments. Although Brazilian scientific production in VR for autism is still incipient in international journals, these national initiatives suggest a promising field that faces unique contextual challenges. Adapting tools to the socioeconomic and cultural diversity of the country, optimizing for accessible hardware, and developing flexible protocols emerge as critical needs for successful implementation. Collectively, these investigations attest to the technical and clinical feasibility of VR interventions in our country and highlight recurring challenges. Among them are adaptation to socioeconomic and cultural diversity, optimization for more accessible hardware, and the development of flexible protocols that consider the heterogeneity of the autism spectrum in the Brazilian population.

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SM: Conceptualization, Data curation, Investigation, Project administration, Writing – original draft.
RFG: Data curation, Writing – review & editing.
LLG: Data curation, Writing – review & editing.
MGC: Formal analysis, Supervision, Validation, Visualization, Writing – review & editing.
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