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Virtual Reality in Pediatric Psychology: Benefits, Challenges, and Future Directions

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Abbreviations: VR – virtual reality; VE – virtual environment; RCTs – randomize clinical trials; HMDs – head-mounted displays

Contributors' Statement Page

Dr. Thomas Parsons conceived and developed the initial draft. Dr. Giuseppe Riva, Professor Sarah Parsons, Dr. Fabrizia Mantovani, Dr. Nigel Newbutt, Dr. Lin Lin, Dr. Eva Venturini, and Dr. Trevor Hall worked with Dr. Thomas Parsons to enhance the original draft and develop it into the final draft.

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Abstract

Virtual reality technologies allow for controlled simulations of affectively engaging background narratives. These virtual environments offer promise for enhancing emotionally relevant experiences and social interactions. Within this context virtual reality can allow instructors, therapists, neuropsychologists, and service providers to offer safe, repeatable, and diversifiable interventions that can benefit assessments and learning in both typically developing children and children with disabilities. Research has also pointed to virtual reality's capacity to reduce children's experience of aversive stimuli and reduce anxiety levels. While there are a number of purported advantages of virtual reality technologies, challenges have emerged. One challenge for this field of study is the lack of consensus on how to do trials. A related issue is the need for establishing the psychometric properties of virtual reality assessments and interventions. This review investigates the advantages and challenges inherent in the application of virtual reality technologies to pediatric assessments and interventions.

Background

Virtual reality for assessment, therapy, learning, and rehabilitation

Virtual Reality (VR) is an emerging technology that can be considered the result of the evolution of existing communication interfaces towards the various levels of immersion.[1] An important difference between VR and other media or communication systems is the sense of presence, the "feeling of being there".[2] Through merging of educational and entertainment environments (e.g., gamification, VR, and edutainment), coupling of immersive technologies (e.g., head mounted displays) with advanced input devices (e.g., gloves, trackers, and brain-computer interfaces), and computer graphics, VR is able to immerse users in computer-generated environments that reflect real-world activities.[3,4,5] Within this context, and the field of VR more widely, there are many technologies that have been developed and used in educational and clinical settings. As such, there is a wide range of hardware available to researchers and practitioners. Table 1 provides a synthesis of currently available technology and highlights the various specifications, costs and user interactions across a spectrum of devices. While these virtual reality technologies differ in their specification, size and portability, the key affordance of VR (i.e. immersion, presence and ecological validity) remains. Therefore, it is likely some key findings (i.e. acceptance, presence, immersion, limited negative effects) from previous work could be applicable across many current technologies.[6] While the quality, graphic fidelity, and refresh rates might vary across platforms (as highlighted in Table 1), the nature of the VR immersive environments and presentation of visual (and audio) stimuli, help to ensure similar user-experiences acorss all platforms.

The availability of much more affordable devices (as shown in Table 1) illustrates that VR hardware has the potential to become more accessible to a much wider demographic than before. Therefore, the extent to which the key affordance of presence is supported by the different VR technologies is a central research question for the field if we are to really understand what features supported by the different hardware are necessary and sufficient for supporting effective and authentic assessment and learning with VR for a much wider group of children. In other words, VR offers an important pathway for narrowing the digital gap nationally and internationally if we can establish how a sense of presence can be achieved in the most accessible and available technologies.

**** INSERT TABLE 1 ABOUT HERE ****

Current State of the Science

Recent advances in VR technology allow for improved efficiency in administration, presentation of stimuli, logging of responses, and data analyses.[7] These features have allowed VR platforms to emerge as promising tools for pediatric cohorts in a number of domains. Examples from recent research and reviews (within the past 10 years) include:

- Neurocognitive assessment[8,9]
- Psychotherapy[10,11]
- Rehabilitation[12,13]
- Pain management[14,15]
- Prevention and treatment of eating disorders[16,17]
- Communication training[18,19]
- Vocational readiness training[20,21]
- Social skills training[22,23]

Within this context VR technology can allow instructors, therapists, neuropsychologists, and service providers to offer safe, repeatable, and diversifiable interventions that can benefit assessments and learning in both typically developing children and children with disabilities.[24]

Entertainment and educational environments

Virtual and augmented reality platforms are rooted in gaming, simulation, and entertainment expriences. Augmented reality overlays virtual objects over a real environment, resulting in a mixed reality that can be used for student-centered learning scenarios (REF chen). Given the merging of educational and entertainment environments virtual and augmented environments have the potential to be a "positive technology" that can improve the quality of children's experiences.[25,26] For example, Active Worlds, Second Life, ecoMobile, are platforms that have been advocated as promoting more active exploration, engagement, student-centered, and hands-on learning, better understanding of complex subjects, and more authentic, collaborative, and experiential opportunities for solving real-life problems.[27-29]

The "Google Expeditions Pioneers Program"[30] is a good example of this emerging trend, which allows teachers to take their students on virtual journeys using an application installed on the students' smartphones. In addition to being teaching and learning tools, VR allows for data capturing of learners' attitudes, behavior changes, and "aha" moments. Such a portfolio of assessments helps serve as foundation for educators to develop formative assessment loops, address individual needs, and design better learning opportunities.[31] In higher education, VR technologies may help prepare students for future work places in STEM, business, and medicine. This is especially the case in training skills and performance that carry high risks (e.g., driving, flying, conducting a surgery, managing investments).

A focus on positive technology also provides new ways of thinking about the locus, and therefore, solutions of the different challenges or problems faced by children with neurocognitive difficulties.[32] For example, rather than developing VR to fix the impairments of the child, VR could be developed to provide better insights and awareness into the difficulties experienced by individuals so as to promote better understanding from the wider public. The "Too Much Information" project of the National Autistic Society in the United Kingdom is a good example of this kind of approach (http://www.autism.org.uk/VR).

Future Research

One area of future research that will be of interest to clinical scientists is the performance of performing large scale randomized clinical trials. While quantitative reviews of VR interventions have revealed statistically large effects on a number of affective domains.[33] Future studies can increase the confidence in these findings through the inclusion of control groups and performing randomized clinical trials. Furthermore, there is need for future studies aimed specifically at establishing the ecological validity and other psychometric properties of VR assessments and interventions for clinical, social, and affective neuroscience research.[34]

Following the establishment of psychometric properties of VR protocols, future work will be assisted by adopting procedures for standardized reporting of RCT outcomes. This is especially important in the context of new designs and relatively untested features of technology. A potential aide for future research can be found in the Consolidated Standards of Reporting Trials standards that ensures readers to have the basic information necessary to evaluate the quality of a clinical trial.[35]

Recommendations

Clinicians and Providers

While VR-based neuropsychological assessments are often referenced for their promise of enhanced ecological validity[3], there are potential practical limitations that should be considered. Some VR-based assessments offer automated presentations that do not allow flexibility for clinical examiners to interrupt or “test the limits” during assessment. Future development of VEs should allow for flexible presentations, wherein clinicians may adjust graphics, stimuli, and task parameters via an interactive user interface. Moreover, the dearth of established guidelines for the development, administration and interpretation of these assessments could lead to important psychometric pitfalls. While these limitations are important to consider, advances in VR technology will allow for continued enhancements in approximations of real-world cognitive and affective processes.

There is also the potential for unintended negative effects of exposure to virtual environments--stimulus intensity, if taken too far, may exacerbate rather than ameliorate a deficit. This is an important concern though there is no evidence from two different studies with students diagnosed with autism that they experience negative effects over and above those experienced by students without autism.[36, 37.] While these two studies tend to suggest that negative effects were self-reported as low, they involved screen-based virtual environments. As we adopt newer and more immersive technologies (i.e. HMDs) it is important to consider the potential negative effects (i.e. dizziness, sickness, displacement) to ensure that wearable technologies (e.g., HMDs) can provide an acceptable space for children to use; especially children with disabilities. With this said, there is some evidence that suggests children do not experience HMDs any more negatively than screen-based media.[9,38] Taken as a whole, the need to validate and confirm acceptance of evolving and very new technologies, is evident and there is need for more research in this domain.

With this in mind, there is a need, before we enter into VR RCTs, design, and intervention programs, to fully validate, understand users' perspectives, and ensure that ethical guidelines are established.[39] This could be done in either lab-based or in situ settings, however, careful attention will need to be placed on developing protocols to ensure the voices of participants are always heard in any research endeavor involving VR technologies.

The introduction of affordable head-mounted displays (e.g., HMDs like Oculus Rift; Samsung Gear VR; Google Cardboard) makes VR an increasingly popular entertainment and learning venue. However, the unmonitored use of VR for entertainment has raiseed concerns over the years. For example, Segovia and Balienson[40] conducted a study examining the use of VR in children. They found that children exposed to virtual environments do not always differentiate between VR-based memories and memories formed in the real world. While these findings need to be replicated in additional studies, the implications demonstrate that unmonitored and entertainment based VR platforms may not be appropriate for all children. Moreover, the merging of VR with gaming technologies will open VR to concerns that have been raised for gaming and entertainment technologies: sedentary lifestyle, cyber addiction, violence, social isolation, desensitization, and safety. Additional research is needed in these areas.

Policy Makers

An important challenge in the design and development of VR technologies is the difficulty involved in putting together interdisciplinary research teams for developing appropriate interventions.[41] Furthermore, there is increasing recognition that representatives of intended user groups should also be included in order to achieve a better fit between identified needs and proposed solutions.[42] Though not without difficulties, such approaches also align with increasing awareness of the need to involve, for example, members from the clinical and educational communities in these research agendas more widely.[43] Our main recommendation here is that policy makers, including funders, need to support and encourage more user-centred design approaches to VR development and evaluation in order to ensure that end-users' needs and priorities are more effectively met in research programmes and projects.

Educators

As mentioned earlier, VR offers great potentials for teaching, learning, assessment, and interventions. Although VR can provide a safe environment for students to gain skills, it usually requires actual experiences to fully master a skill. Poorly designed VR environments may lead to misunderstanding or faulty training results. In addition, VR can provide authentic assessments and interventions in schools where children and adolescents spend most their time[44]. The potential for VR technologies to be deployed in schools and used for distance learning[45] is encouraging even if challenging. Its potential will be deepened by the diffusion of VR on smartphones.

It is the working group's consensus that investigations into these future research endeavors have potential to inform policy, theory, and praxes. Specifically, the addition of virtual reality platforms to pediatric assessments and interventions offers an opportunity for advancing our understanding of the cognitive, affective, psychosocial, and neural aspects of children as they take part in real-world activities.

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VR Systems

PC Based		Mobile Based			Console Based	Standalone	
Oculus Rift	HTC Vive	Samsung Gear VR	Google Cardboard	Google Daydream	Playstation VR	AllWinner VR	Snapdrag V
599 US$	799 US$	99 US$	10-50 US$	69-149 US$	399 US$	99-249 US$	399-45
High End PC (>1000 US$)	High End PC (>1000 US$)	High End Samsung Phone (>600 US$)	Middle/High end Android phone or iPhone (>299 US$)	High End Android Phone (>499 US$)	PS4 (299 US$) or PS4 Pro (399 US$)	None	No
2160x1200	2160x1200	2560x1440	Depends from the phone (minimum 1024x768)	Depends from the phone (minimum 1920x1080)	1920x1080	1920x1080	2560x
90Hz	90Hz	60Hz	60Hz	90Hz minimum	120Hz	60Hz	70
110 degrees	110 degrees	101 degrees	from 70 degrees	96 degrees	100 degrees	90 degrees	
Medium/High: head tracking (rotation) and positional tracking (forward/backward)	High: head tracking (rotation) and volumetric tracking (full room size – 15ft x15ft - movement)	Medium: head tracking (rotation)	Medium: head tracking (rotation)	Medium: head tracking (rotation)	Medium/High: head tracking (rotation) and positional tracking (forward/backward)	Medium: head tracking (rotation)	Medium/H tracking (and pos track (forward/b
High (using a joystick or controllers)	High (using controllers)	Medium (using gaze, a built in pad or joystick)	Low (using gaze or a button)	Medium (using gaze or joystick)	High (using a joystick or controllers)	Medium (using gaze, a built in pad or joystick)	Medium gaze, a b or joy
Oculus Store	Steam Store	Oculus Store	Google Play or IOS Store	Google Play	Playstation Store	Google Play	Googl