Immersive Horizons: Navigating the Impacts of Virtual Reality on Children and Families

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1 Background

Virtual reality (VR) is a computer-based technology that allows users to engage with multimedia content that can closely emulate real-world experiences. By leveraging VR's distinctive features, users feel as though they are immersed in an alternative environment where they can interact with items and characters in a simulated space in real time. Most modern VR systems provide users with a panoramic, 360-degree perspective of the virtual surroundings and often incorporate user interfaces designed to facilitate interaction with objects and navigation within the virtual space.

Although VR technology has existed for decades, recent advances in computing paved the way for VR to fundamentally transform how humans of all ages interact with digital technology and revolutionize many aspects of our lives. It is estimated that the upcoming generation will spend up to 10 years immersed in VR throughout their lifetimes [1].

New technology often raises concerns about its potential impact on children [2], and VR is no exception. The immersive, multisensory, and embodied nature of VR sets it apart from previous technologies, leading to both increased potential and concern. Since childhood is a period

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of high plasticity and growth [3], the potential impact of VR might be even more significant for children than for adults. Yet, many questions remain unanswered. This chapter summarizes the current state of knowledge and the remaining questions about VR's effects on children.

2 Current State

The current understanding of children using VR is still in its early stages. A limited number of empirical studies have explored the effects of VR on child development and education, but these studies face two significant constraints. First, they primarily examine short-term effects, as the technology remains under development, particularly for children. Second, until 2023, guidelines established by VR experience providers (e.g., Meta) and equipment manufacturers advised against the use of VR for children under 12 or 13 years of age. However, it is noteworthy that even during that time, children younger than 13 were engaging with VR [3].[1] Despite these limitations, some emerging themes have surfaced from this nascent research, and insights can be gleaned from studies examining children's use of other technologies.

2.1 Pain Distraction

Perhaps the only area of psychological VR research with clear, unambiguous outcomes is its use to distract from pain and anxiety in medical procedures. Research on VR as a distraction tool with children 4 years and older has revealed effectiveness in a range of procedures, such as venipuncture, chemotherapy, burn wound care, dental treatments, and immunizations [4, 5]. By creating engaging and immersive virtual environments, VR diverts the child's focus from the pain and anxiety associated with these procedures, reducing the need for sedatives and analgesics. The fact that VR is so effective at mitigating pain and anxiety in medical settings highlights its powerful ability to capture children's attention and fully immerse them. This observation raises important questions about the potential impact of VR on children's development, learning, and overall engagement with the real world outside of clinical settings.

2.2 Lessons from Pediatric Psychiatry

While child psychiatry applications of VR are largely outside the scope of this chapter, it is notable that VR is increasingly explored as a tool in child psychiatry, with applications in assessment, treatment, and research [4, 6]. One vibrant topic in childhood VR research is using VR to assess and treat neurodevelopmental disorders. For example, VR has shown promise in assessing children for attention disorders by examining attentional focus in a simulated classroom environment with built-in distractions [7]. These studies find that assessments implemented in a virtual classroom environment are at least as effective and sometimes more so than some traditional assessments at distinguishing between children with and without attention disorders. Like findings on pain distraction, these results further demonstrate the extent to which simulated environments in VR are processed as real by school-age children.

2.3 Education

VR is emerging as a promising tool in childhood education, promising several benefits for cognitive development and skill enhancement. VR has captured the attention of educators because of its ability to present abstract concepts concretely and in 3D. Indeed, the educational VR applications with the most promise are those that allow children to explore information from different perspectives or to explore novel environments [8]. Exploration from different perspectives facilitates mental rotation, memory, spatial represen-

[1] And, and as of September 2023, the minimum age for some Meta headsets has been lowered to 10+ years with a parent-managed account.

tation, effective problem-solving, and cognitive modifiability [9, 10]. Several recent reviews highlight the potential educational advantages of VR, particularly in STEM subjects, where tasks requiring visualization and interactivity greatly benefit from the VR medium [11–14]. However, there are significant limitations to the existing research on the effectiveness of VR in childhood education. These include a lack of studies focusing on arts education, limited quantitative measures of learning [15], and limited comparisons to other learning methods [4, 12].

Moreover, although VR technology has become more affordable and accessible, many obstacles remain to implement VR-enhanced learning programs in schools, including inadequate teacher training and IT services which inhibit the creation of VR content and its implementation in classrooms [16]. Additionally, although platforms and devices that afford social collaboration within VR immersive environments are increasing in number, they remain rare. In utilizing VR in isolation, the potential educational benefits may be offset by the sacrifice of social interaction and collaboration, which are well-established factors in promoting learning [17]. Finally, this technology is still prohibitively expensive for many, potentially creating another digital divide.

2.4 Safety Training

By simulating real-life situations in a safe and controlled environment, VR offers a secure environment for children to learn vital safety skills, such as recognizing potential risks at a beach or escaping a riptide [18], by simulating realistic conditions. This immersive experience enables children to practice decision-making and problem-solving without risk while boosting their motivation and interest in safety education, but notably, few studies have utilized modern VR technology in controlled experiments. Nevertheless, several effective implementations exist, and with advancing VR technology, its role in teaching safety skills to children will likely expand, opening new doors for engaging safety education.

2.5 VR and Visual Development

One area warranting further long-term investigation is the potential impact of VR on ophthalmological development and the immediate effects of this highly immersive and close-up technology. Initial studies suggested that children could be susceptible to issues like postural instability (difficulty maintaining balance) or decreased stereoacuity (depth perception from binocular cues) [19]. However, more recent research has not found an increased risk of VR-induced seizures in children with photosensitive epilepsy [20] or negative impacts on visuomotor function, postural stability, and motion sickness [14, 21]. Despite these findings, there are no data on whether such effects could emerge if children use VR for extended periods in a single sitting or consistently over months and years, or at younger ages. Thus, questions remain regarding long-term implications.

2.6 Insights from Screen Media Research

Finally, while VR is more immersive than typical screen media, some insights will likely prove relevant as we consider the impacts of VR on developing children. For example, research has shown that increased touchscreen device usage in infants and toddlers is associated with reduced sleep [22], a shift toward saliency-driven attention, and diminished cognitive control of attention [23], but also an earlier achievement of developmental milestones for fine-motor (e.g., finger) control compared to low touchscreen users [24]. Associations between cognitive development and the use of other screen mediums, including television [25] and video games [26], are well established. While causal evidence from randomized controlled trials is limited, the mechanisms by which screen time may influence developing cognition are apparent.

3 Future Research

The implications for VR for children and human society generally are vast and difficult to predict. The ways that VR is integrated into our lives will be influenced by technological advances, cultural acceptance, and scientific research on its psychological and physical effects. Its particular implications for children, whose brains are undergoing tremendous development and whose early experiences can have lifelong impacts, are even less predictable. Several areas deserve immediate investigation.

3.1 What Are the Potential Differential Impacts of VR on Children of Different Ages?

Children's experiences with digital interactions in VR differ from those with other technologies. Since VR enhances immersion and increases the intensity of children's interactions, it has the potential to affect their sense of embodiment. This can be positive, as learning is often supported by engaging, meaningful, iterative, socially interactive, and joyful experiences [27]. However, it may also amplify negative experiences, such as cyberbullying, losing track of time, isolation, and mental health concerns. Additionally, the intensity of the sensory experience and the complexity of the content should be considered. Fast-paced and fantastical content in videos can deplete children's executive functions, which are essential cognitive skills for regulating behavior [28]. The intensity of VR experiences, particularly those with minimal interaction [29], may have even more significant depletion effects.

As seen in the screen time debate, the impacts of technology on children are rarely entirely good or bad. Factors such as child age, quality of experience, time spent, individual differences/susceptibility, and the presence or absence of a caring adult to help navigate (and limit) the experience are all critical considerations. These effects may vary based on age, experience, and individual differences/susceptibility.

Therefore, more studies are needed to examine the longitudinal associations between VR use and child development in cognitive (especially attention control, vision, and executive functions), social, physical, creative, and motor development aspects. Concurrently, randomized controlled trials should be used to investigate the direct impact of VR use, with strong ethical controls to mitigate the risks of introducing VR.

As of 2024, most vendor guidelines recommend a minimum age of 10+ or 13 for VR usage. But as these headsets become more mainstream, younger children will use them, just as they use social media that shares similar age requirements [30]. To our knowledge, minimum ages for VR usage set by VR content and equipment vendors are not predicated on a robust evidence base concerning the specific developmental, cognitive, or physical impacts of VR technology on younger children. Instead, it appears to reflect a precautionary stance adopted by developers and manufacturers, driven by market acceptance, headset size, legal liability, and political pressure. As VR technology becomes more familiar to consumers, and its integration into daily life more seamless, we should expect that children younger than 10–13 years will increasingly encounter opportunities to use VR, particularly as they observe older family members engaging with the technology. The desire to include younger children in these experiences as well as children's own interest in engaging with VR may result in use that outpaces our scientific understanding of the implications, underscoring the need for research that transcends arbitrary age limits and examines VR's impact across ages.

3.2 How Will Increasing Familiarity with VR Technology Impact the Long-Term Effectiveness of VR Applications for Children?

As children become more accustomed to VR, researchers should assess how familiarity might influence the sustained benefits of VR applications in various domains, such as education, pain

distraction, and safety training. Will the novelty and engagement of VR experiences decrease over time, leading to reduced effectiveness, or will continuous advancements in technology and the personalization of experiences counteract potential diminishing returns? Investigating the relationship between VR familiarity and its effectiveness in these areas will inform developers and educators how to adapt and evolve VR content to maintain its usefulness.

3.3 How Will Caregiver VR Usage Influence Parent–Child Interactions and Relationships, and What are the Implications for Children's Development?

If VR use becomes prevalent by adult caretakers, children might be regularly exposed to people using VR even if they are not using it themselves. This is important because caregiver use may affect the quality and quantity of caregiver–child interaction opportunities. It also normalizes and models VR usage from a very young age in the way parental usage of touchscreen devices does today. Based on existing data on screen use, there are warning signs about caregiver screen use impacting adult responsiveness and children's behavior [31]. Thus, not only will children's experiences with VR be more immersive, but so will their caregivers, which may impact caregiver–child relationships.

3.4 How Can We Leverage the Data Generated by VR Use for Good While Protecting Children's Data and Privacy from Targeted Advertising or Worse?

Major privacy concerns were highlighted by a recent Common Sense Media report highlighting the extensive personal data collected by headsets, including information such as body and eye position, facial expression, and skin color [32]. Given that individuals are personally identifiable with astonishingly limited use (e.g., less than 120 seconds), privacy remains paramount. Relatedly, research into memory formation in VR has not only shown that children can learn and generalize from VR materials but has also examined how false information and impossible events viewed in VR environments can impact children in real life [33, 34]. Specifically, VR experiences may make young children susceptible to forming false memories in VR that persist in real life; and to believe that impossible events are possible. This creates serious concern about children experiencing VR "realities" potentially as harmful as real life (e.g., abuse, bullying, and manipulation).

On the other hand, one can imagine the potential for individualized experiences based on an individual child's interests, knowledge, abilities, and goals. Today's curricula, texts, and even videos are somewhat one-size-fits-all—but VR and the use of AI and adaptive technologies have the potential to be individualized resources that can meet children exactly where they are and provide personalized experiences and information. But again, this also heightens the potential risk of targeted marketing and victimization as these devices generate more data than ever.

4 Recommendations

- *Policymakers*: Policymakers must recognize that our understanding of the potential impacts of VR on children is still in its infancy. As they are called upon to establish guidelines to protect children, consulting with scientists, researchers, pediatricians, and parents is essential, rather than relying solely on assurances of potential and safety from manufacturers. Several outstanding questions need to be addressed, such as who should regulate virtual environment platforms, and if regulation were to occur, how to balance the need to protect the public with the freedom of expression in such platforms. Additionally, as policymakers work toward providing greater access to VR technology, they should also consider issues related to diversity and equity, striving

to bridge the digital divide and address potential disparities in access, content, and representation [34]. Ensuring that the benefits of VR technology are distributed fairly while mitigating potential negative impacts will require a comprehensive approach, including research, prospective data collection, and proper use of the collected data.

- *Educators and educational systems*: The prospect of VR enhancing education is undoubtedly enticing; however, we must remain cognizant of the limitations in our current understanding of children's learning experiences with VR. As of now, there is no evidence to suggest that VR-based programs outperform those developed by passionate, dedicated, and experienced educators. In light of our ongoing exploration of VR in education, it is advised that schools partner with researchers to study VR's potential to enhance learning in educational settings rather than relying on it as a replacement for high-quality teaching. Further, evidence-based professional development for educators and IT support will be necessary so that VR implementations add minimal disruption to the classroom.
- *Researchers, clinicians, and parents*: As virtual reality (VR) becomes more prevalent among children and adolescents, it is essential to consider how to protect them from potential harm and determine who will regulate its use. While current research has provided some insight into the possible long-term effects of VR, more is needed to provide clear guidance to parents and clinicians. As more research becomes available, it will be crucial to develop effective tools to help parents mitigate the risks for their children based on their age, developmental skills, and abilities. In summary, it is essential to exercise caution when using VR with young people and to take steps to ensure that they are adequately protected from any potential harm.
- *Developers*: A significant concern with VR is its tendency to be an individual activity, which can reduce opportunities for social interaction because it immerses the user in a virtual world isolated from those physically around them. This isolation limits shared experiences and direct interactions with family or peers during childhood, a time when social interaction is critical. To address this, we encourage developers to go beyond implementing typical parental controls such as screen time limits, content filtering, and activity monitoring and to focus on creating VR content and platforms that support group experiences, enabling children and their families or friends to enjoy VR together—in either the real or virtual world. Innovating VR games and educational activities for groups can transform VR from an isolating to a collaborative experience. Developing virtual spaces for interactive participation makes VR more engaging and promotes the developmental benefits of social interaction [35]. By prioritizing shared VR experiences and enhancing parental controls so that social interaction is not displaced by solo VR experiences, we aim to enhance the technology's role in supporting rather than detracting from children's social development.
- *All stakeholders*: Safe, effective, and age-appropriate experiences designed to support social, emotional, physical, and cognitive outcomes are the goal, but this will require a multi-sector approach. We recommend that teachers, designers, clinicians, and educators collaborate to provide a holistic approach to protecting children and using VR to enhance their lives. Equity and diversity must also be centered in designing and implementing VR technology to avoid bias, discrimination, and access issues. This will necessitate large-scale, multicenter, longitudinal research programs involving researchers, clinicians, families, hardware and software developers, and policymakers.

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