Digital Playground: Is the Metaverse safe for my child?*

Liquan Liu[1,2,*,†], Carlos Alfredo Tirado Cortes[3,†] and Howe Yuan Zhu[3,†]

[1]Graduate School of Psychology, University of Technology Sydney, 100 Broadway, Chippendale, Sydney, NSW 2008, Australia
[2]School of Psychology, Western Sydney University, 56 Second Avenue, Kingswood, Sydney, NSW 2747, Australia
[3]School of Architecture, Design and Planning, University of Sydney, Camperdown, Sydney, NSW 2050, Australia

Abstract

The Metaverse has been rapidly expanding in content, form, and user engagement, yet there remains a critical gap in discussions regarding its impact on developing children. While consumer-grade Virtual Reality Head-Mounted Displays have made immersive experiences widely accessible, the question of whether and how young children should engage with these technologies remains largely unanswered. This position paper examines the inclusivity and developmental appropriateness of the Metaverse through the lenses of technology, human-computer interaction, and child psychology. Focusing on physical, cognitive, and socioemotional development, we identify key variables that shape children's interactions with virtual environments, including the display of virtual information, levels of immersion, and the vividness of virtual agents. We highlight both opportunities and risks, from the potential for enhanced learning and engagement to concerns about accessibility, safety, and developmental readiness. Additionally, we emphasize the need for adaptive design features that accommodate diverse abilities, ensuring an inclusive and equitable Metaverse experience for young users. Through this paper, we aim to initiate a broader conversation on how researchers, policymakers, and developers can work toward creating child-friendly digital spaces that balance innovation with developmental well-being. By addressing the unique needs of young children, we advocate for a Metaverse that is not only immersive but also safe, accessible, and developmentally appropriate.

Keywords

Metaverse, child-technology interaction, head-mounted display, immersion, virtual agents

1. Introduction

The Metaverse is a near-virtual landscape with a complex societal ecosystem encompassing diverse populations. It manifests in various forms, in Virtual (VR), Augmented (AR), Extended (XR), or Mixed Reality (MR) technologies, as 2D/3D visual projections or screen-based interfaces. The Metaverse has been applied in adolescent learning contexts [1], for instance, in the interactive manipulation of 3D designs to increase engagement and learning of 2D visuals [2]. However, the Metaverse's role in early childhood learning and development remains underexplored. Ensuring inclusivity and accessibility for young children is essential, as they face unique opportunities and challenges in these environments.

On the one hand, studies have shown that Head-Mounted Display (HMD) VR supports learning across age groups, particularly in science education, skill development, and virtual simulations [3, 4]. Among elementary-aged children (5–11), VR has been linked to improved performance in science [5, 6, 7], social sciences [8], mathematics [9, 10], speaking [11], and writing [12, 13, 14, 15, 16]. For middle schoolers (11–13), VR supports mathematics [17], science comprehension [18, 19, 20], listening [21], and reading [22]. However, language learning gains appear later [23, 24]. Broadly, VR enhances motivation and interest in learning [25, 26, 27, 28, 29], and may promote creativity [30, 31], though findings vary [16].

On the other hand, VR presents challenges with studies reporting cybersickness, postural instability, and discomfort from headset use [32]. These limitations raise accessibility concerns: Can all children,

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*Corresponding author.
†These authors contributed equally.
liquan.liu@uts.edu.au (L. Liu); carlos.tiradocortes@sydney.edu.au (C. A. T. Cortes); howe.zhu@sydney.edu.au (H. Y. Zhu)
https://profiles.uts.edu.au/Liquan.Liu/ (L. Liu);
https://www.sydney.edu.au/architecture/about/our-people/academic-staff/carlos-tiradocortes.html (C. A. T. Cortes);
http://www.sydney.edu.au/architecture/about/our-people/academic-staff/howe-zhu.html/ (H. Y. Zhu)
0000-0001-8671-5098 (L. Liu); 0000-0003-0626-0914 (C. A. T. Cortes); 0000-0003-0775-887X (H. Y. Zhu)

including those with physical or cognitive differences, fully benefit from these experiences? Other side effects resemble those from excessive smartphone or gaming use [33]. As a result, some manufacturers restrict VR headsets to users aged 13 and older [34]. Addressing these issues is key to ensuring that the Metaverse does not exacerbate digital inequities.

With technology advancing rapidly, the Metaverse will likely play a significant role in shaping early childhood development. Yet, few design guidelines exist for this population [35]. How can we ensure these environments are not only engaging but also safe, accessible, and developmentally appropriate? This paper explores the Metaverse landscape through the lens of children's physical, cognitive, and socioemotional development, identifying current issues, potential solutions, and areas for future research.

2. Metaverse Technology for Children

HMDs offer the most immersive way to access the Metaverse, but their suitability for children raises physical and physiological concerns. Children experience cybersickness, or the sense of discomfort, nausea, and disorientation during or after VR use [36]. However, they experience it at milder levels than adults [32]. While eyestrain and impacts on visual development have been concerns, recent reviews found no lasting effects on children's vision [33]. Only one documented injury from VR in children involved nasal trauma after three months of prolonged HMD use [37]. Despite limited evidence of harm, major companies restrict VR headset use for children under 13 [34], creating a gap in accessible hardware for younger users.

Researchers are exploring alternative technologies to ensure inclusive and developmentally appropriate Metaverse access. VR has demonstrated potential in supporting children's cognitive development, sometimes outperforming traditional platforms [38], and has proven safe for children with disabilities [39]. However, access typically remains limited to laboratory settings with specialized equipment. Semi-immersive alternatives like large curved displays [40], CAVE environments [41], and 360-degree cinema setups [42] offer essential alternatives to HMDs. For example, Kinect-enabled CAVE configurations reduce projector-based VR system costs while supporting natural interaction [43]. These alternatives improve accessibility for children generally and have successfully engaged neurodivergent children, including those with autism. Further research is needed to expand these technologies across educational and clinical contexts.

3. Physical Development

3.1. Theoretical considerations

As highlighted by social learning theories [44, 45], children's physical development is influenced by both biological maturation and environmental interactions. As the Metaverse becomes part of children's lived environments, its potential to promote physical activity across different abilities must be considered. Health authorities recommend (Table 1) regular physical activity and limited screen time for young children [46, 47, 48], yet compliance remains low.

VR and AR may offer engaging movement-based alternatives if designed to be inclusive, although risks such as cybersickness need to be addressed. The video deficit hypothesis suggests that infants learn less from screen media compared to live interaction [49, 50], although recent analyses show mixed outcomes [51]. Regardless, social interaction remains critical for screen-based learning [52], and this warrants serious considerations among children with sensory or motor impairments. It is worth noting that as perceptual abilities develop with age, older children have demonstrated improved spatial reasoning through immersive technologies, with positive results observed in virtual lab environments for subjects like stereochemistry [18].

Group	Age	Physical activities	Screen time
Infants	0-1 year	Interactive floor-based play, and at least 30 minutes of tummy time for babies per day	no screen time
Toddlers	1-2 years	at least 3 hours of energetic play a day	no sedentary screen time
Preschoolers	3-5 years	at least 3 hours a day with 1 hour being energetic play	no more than 1 hour of sedentary screen time per day
Children	5-13 years	At least 1 hour of moderate to vigorous activity involving mainly aerobic activities per day; vigorous activities should be incorporated at least 3 days per week; several hours of light activities per day	no more than 2 hours of sedentary screen time per day

Table 1
Physical activity guidelines for Australian children retrieved from Australian Department of Health [53]

3.2. Virtual Embodiment and Sensorimotor Development Across Childhood

3.2.1. Virtual Embodiment and Sensorimotor Interactions

Virtual embodiment plays an essential role in the effectiveness of user acceptance and interaction within virtual environments in the Metaverse [54]. Virtual embodiment relies on a child's sense of agency and ownership over their virtual self, which is represented through an avatar [55]. This avatar serves as the primary medium through which children navigate and interact in the Metaverse. When the virtual embodiment is successful, sensorimotor synchrony allows for naturalistic control of the avatar via visual, haptic, and proprioceptive feedback mechanisms [56]. These sensorimotor interactions can be mediated through HMDs, controllers, motion capture, or keyboard and mouse interfaces.

Children exhibit unique sensorimotor responses in virtual spaces and show strong adaptability to avatar control schemes [57]. Motor skill development varies across age and gender, with bilateral coordination improving through adolescence, though slowing after age 12 [58]. Younger children may initially struggle with complex motor tasks in the Metaverse but often improve over time. Exergames designed to promote physical activity have been shown to enhance physical health and refine motor skills [59, 60]. Similarly, virtual body training can improve real-world motor control and build confidence in physical behaviours [61, 62].

3.2.2. Physical Considerations during Embodied VR Experiences in the Metaverse

Extended use of the Metaverse may pose physical challenges for children, particularly when sensorimotor mappings between their bodies and avatars do not align. This mismatch can lead to unnatural postures, such as those associated with "Gorilla Arm Syndrome" [63]. Excessive immersion without sufficient physical movement may also contribute to sedentary behaviour [64]. As children grow, their sensorimotor systems change in ways that differ from adults, potentially leading to disassociation or coordination issues [65]. Vision development is another area of concern, with extended VR use linked to eye strain and potential impacts on visual health in younger users [66].

In addition to physiological effects, virtual embodiment can affect cognitive and psychological development. Younger children, whose ability to distinguish between real and simulated experiences is still developing, may be particularly susceptible to misinterpreting virtual experiences as real [67]. Virtual environments may also lead to overconfidence in physical abilities, which could result in risky behaviour when those skills are transferred to real-world settings [68]. While the Metaverse offers rich opportunities for embodied learning and motor skill development, its design must account for these risks to ensure that experiences are developmentally appropriate and supportive of children's physical and emotional well-being.

4. Cognitive Development

4.1. Theoretical considerations

Cognitive development in early childhood is shaped by interaction with the environment, which helps form perceptual categories and neural pathways [69, 70]. The Critical Period Hypothesis highlights that abilities such as language are best developed during early windows of neuroplasticity [71]. As the Metaverse becomes a part of children's learning, it is essential to ensure that their cognitive needs are supported. Embodied cognition theory suggests that learning is grounded in sensory and motor experiences [72, 73, 74], and Metaverse environments that incorporate movement, spatial interaction, and multisensory input can enhance engagement and comprehension [75, 76]. Again, these environments must be designed inclusively to support children with sensory or cognitive differences.

Behavioural theories emphasise how early exposure to associations and emotions such as rewards and fears shapes cognitive and emotional responses [77, 78, 79, 80], supporting the use of positive reinforcement in digital learning tools [44]. However, digital materials typically focus on superficial stimulation rather than deep cognitive engagement [46], overlooking the gradual development of memory and symbolic thinking in children [51]. Inaccessible interfaces and limited input options can exclude children with disabilities, highlighting the need for universal design principles in Metaverse experiences. Research has shown that VR can enhance attention [81], problem-solving skills [7], and self-efficacy [19, 27], while also promoting metacognitive awareness and learning engagement across age groups [6, 30, 31]. A cognitively inclusive Metaverse must provide flexible, personalised learning that aligns with children's diverse strengths and challenges.

4.2. Experiential Learning, Confidence, and Attentional Mechanisms

4.2.1. Experience, Confidence, and Conquering Fears

Experiential learning is crucial in early childhood development, fostering cognitive engagement, problem-solving, and adaptability through direct interaction with the environment [82]. VR improves this by providing immersive and interactive experiences that stimulate curiosity, creativity, and knowledge retention [83]. The Metaverse further expands experiential learning, offering children access to historical events, scientific phenomena, and life skills training in safe, controlled settings [84]. Studies highlight VR's benefits in improving engagement, comprehension, and retention compared to traditional methods [85, 86]. Furthermore, AI-driven personalization in VR improves learning by adapting content to individual needs and providing real-time feedback, making education more inclusive [87].

Beyond education, VR can help children confront fears and anxieties, with research demonstrating its effectiveness in reducing acrophobia [88, 89], social anxiety [90], and medical-related distress such as fear of blood draws [91]. By mastering challenges in virtual settings, children can develop resilience and confidence. However, this confidence can also lead to overestimation of abilities, increasing real-world risk-taking [92, 93]. Negative virtual experiences may also result in psychological distress or trauma, contributing to anxiety, avoidance behaviours, or maladaptive coping mechanisms if not properly addressed [94]. While the Metaverse offers vast learning opportunities, careful design is necessary to balance its benefits with potential cognitive and emotional risks.

4.2.2. Role of Attention and Memory Biases

Attentional mechanisms play a central role in how children process and internalise virtual experiences. While VR can effectively capture and direct attention, prolonged exposure to highly stimulating environments may lead to attention fatigue or shifts in attention span. Negative experiences within VR, such as repeated failure or social rejection, can also affect emotional well-being and shape cognitive development [94]. If these negative interactions occur consistently, they may influence children's attitudes toward learning and problem-solving in both virtual and real-world contexts.

Immersive VR experiences also impact memory, particularly in how children distinguish between real and virtual events. Studies show that children can develop memory biases and sometimes recall virtual experiences as if they were real [95]. This phenomenon of false memories raises concerns for emotional processing and learning [67]. As VR and AI technologies become more integrated into children's lives, research and design must focus on age-appropriate content, structured support, and clear distinctions between virtual and real experiences to ensure healthy cognitive and emotional development.

5. Socioemotional Development

5.1. Theoretical considerations

Social interaction is essential for learning, with live, responsive engagement outperforming passive media [96, 97, 52, 98]. Early screen exposure has been linked to poorer language development [99], partly due to missing social cues like eye contact and responsiveness [51, 100, 101]. A study of 16-month-olds found that in-person interactions yielded better learning than nonhuman agents, with webcam interaction producing intermediate outcomes [102].

Moreover, self-recognition and identity, emerging in infancy and shaped by social interaction [103, 104], are also influenced by virtual self-representations. Research shows that avatars can shape children's behavior and identity [105]. Inclusive avatar design—supporting diverse genders, races, and physical abilities—can help children feel accurately and positively represented in virtual environments.

Furthermore, early childhood is a critical period for face perception, with early exposure shaping recognition of facial features across race and species [70]. The other-race effect suggests that infants' ability to distinguish faces across racial groups depends on early experiences [106, 107, 108]. In the Metaverse, it is crucial to design digital agents with diverse, representative features, as these may promote equitable social exposure and engagement in children.

5.2. Socioemotional Development and Avatar Perception in the Metaverse

5.2.1. Avatar Realism, the Uncanny Valley, and Anthropomorphism

The realism of avatars in the Metaverse significantly influences children's social engagement and emotional responses. The uncanny valley effect, where avatars appear almost human but still imperfect, can evoke discomfort and disrupt immersion. While this phenomenon is well-studied in adults, its impact on children is still developing. Research suggests that children are often perceptive to unnatural or eerie behaviours in avatars, which may lead to reduced engagement or avoidance in social interactions [109]. On the other hand, some children show a preference for highly stylised or exaggerated avatars, which may feel more familiar or approachable in a digital setting [110].

As avatars often mediate social communication in the Metaverse, their design plays a crucial role in shaping interpersonal dynamics. Children are particularly sensitive to mismatches between an avatar's appearance and movement, which can affect their willingness to engage [111]. In addition, children frequently anthropomorphise virtual characters by assigning them human-like qualities. This tendency is amplified in the Metaverse, where characters appear responsive and lifelike [112]. Anthropomorphism influences social development and can blur the line between real people and virtual agents, especially when children respond emotionally to virtual characters in ways similar to human interaction [113, 114].

5.2.2. Identity, Self-Perception, and Social Integration in Virtual Spaces

The Metaverse provides children with the ability to customise and embody digital avatars, offering opportunities for self-expression and exploration; however, this flexibility also introduces risks related to self-perception. Repeated use of avatars that differ significantly from a child's real-world body can lead to altered perceptions of identity and appearance [115] and over time, may contribute to self-disassociation, where children begin to feel disconnected from their physical selves due to prolonged identification with their virtual representation [116]. These shifts in self-perception can influence socioemotional development, particularly in environments where social dynamics are mediated through digital interactions. One significant concern is the experience of exclusion within virtual spaces, where, similar to the physical world, children can encounter social rejection, which may negatively impact self-esteem and emotional well-being [117]. If a child's avatar is ignored or excluded by peers, the resulting feelings of isolation can extend beyond the digital environment, making it essential to design virtual spaces that promote positive social inclusion and support healthy emotional development.

VR offers promising tools for enhancing collaboration, communication, emotional engagement, and intercultural competence [6, 24, 30, 31, 118]. To ensure equity, VR must be accessible to children with varied cognitive, sensory, and motor needs. Well-designed Metaverse environments can foster belonging, self-confidence, and support healthy social development both online and offline.

6. A Digital Playground for Children

Interactive technologies are becoming increasingly present in children's everyday lives, yet the effects on development remain poorly understood. The constraints in child research have led to greater focus on older children or adolescents, leaving open questions about how young children perceive and interact with virtual environments. Open questions include: How do young children distinguish real people from virtual agents? What makes digital interactions safe, effective, and developmentally appropriate?

Understanding what defines a "human-like" interaction is critical. Realistic virtual agents may enhance learning and engagement but the long-term effects on early childhood development are unknown. A child-friendly research space is needed to examine children-computer interaction. This space can feature avatars—including parental avatars—and psychometric tools to guide interactive design. Future studies should also assess the effects of display medium (e.g., HMDs, AR, 2D screens) on physical activity, sensory processing, and engagement across age groups.

There are practical implications, especially given increasing regulation, such as Australia's Online Safety Amendment (Social Media Minimum Age) Bill 2024. A dedicated "Digital Playground" would allow researchers to explore children's interactions with avatars in a safe, controlled setting. One focus should be the role of immersion: while highly immersive environments may support cognitive engagement, they may also lead to cognitive overload in younger users.

Virtual agents also influence socioemotional development, yet it is unclear how children perceive these agents or what features support positive interaction. Research should identify how real and virtual agents differ in children's eyes and ensure adaptive tools—like sign language, text-to-speech, and flexible interaction modes—are integrated for accessibility.

Finally, future work must establish design principles for child-appropriate XR: enhancing vividness [119], improving interactivity, and embedding accessibility features. Interdisciplinary collaboration will be key to generating evidence-based guidelines that help shape a safe, inclusive, and developmentally aligned Metaverse for children.

7. Conclusion

As digital media become deeply embedded in daily life, they are reshaping how children grow, learn, and engage with the world. The Metaverse, in particular, brings both promise and concern, with implications for physical, cognitive, and socioemotional development. This paper has outlined key challenges in creating a safe and inclusive Metaverse for young children, emphasizing the importance of age-appropriate design, accessibility, and strong safety measures. Our goal is to support policymakers, educators, and developers in shaping evidence-based guidelines and best practices. Moving forward, interdisciplinary collaboration and targeted research will be essential to ensure immersive technologies support, rather than compromise, early development—helping to build a responsible, child-friendly digital future.

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