

Research Paper

“Someone who has ADHD or someone who has autism should make the rules”: A participatory study of neurodivergent child perspectives on the ethics of extended reality technologies

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ABSTRACT

Extended reality (XR) technologies have the potential to shift the digital landscape for young people's education, play, and social interactions. However, the immersive and data-intensive nature of these technologies also poses risks for young people, with autistic children and/or those with ADHD (i.e., neurodivergent children) experiencing specific vulnerabilities. We conducted an interview study with 21 neurodivergent children ages 8–13, drawing on animated speculative future use scenarios as a discussion prompt, to identify their views on the possibilities and limitations of XR technologies. While their ethical critiques overlapped significantly with those of neurotypical children in prior work, they also offered novel interpretations (e.g., the importance of neurodivergent individuals being involved in XR design; heightened potential for problematic media use with VR). This study contributes to the child-computer interaction community by surfacing the views of a population whose first-person accounts of novel technologies are underrepresented. In addition, our work offers valuable insights into ethical XR research with and design for neurodivergent children, considering their priorities, interests, and concerns.

1. Introduction

Extended reality (XR) technologies have the potential to shift the digital landscape for young people's learning, play, and social interactions (Cortesi et al., 2021). XR technologies include platforms, hardware, and algorithmic processes encompassing virtual reality (VR) (i.e., immerses users in a simulated computer-generated 3D environment), augmented reality (AR) (i.e., adds screen-based digital elements to a real-life view), and mixed reality (MR) (i.e., merges physical and digital world environments with interactive objects). XR systems can involve mobile, desktop, wearable, or ubiquitous spatial computing technologies such as projectors, smartphones, glasses, and head-mounted displays (HMDs) (e.g., Meta Quest, Apple Vision Pro). Artificial intelligence (AI) is increasingly incorporated into XR to create more immersive, interactive, and personalized experiences through intelligent interactions, dynamic content creation, and hyperreal simulations (Reiners et al., 2021). XR is increasing in popularity, reach, and

affordability among families and children, and at younger ages. According to Common Sense Media (Rideout et al., 2022), 17 % of U.S. children ages 8–18 have a VR headset at home, and 22 % of those ages 8–12 have tried VR at least once.

Children who are neurodivergent may be particularly drawn to XR. Neurodiversity is both a theoretical lens focused on acceptance (influenced by disability studies) and a political movement centered on inclusion and accommodation (informed by disability activism) (Rosqvist et al., 2020). Neurodivergence encompasses a range of neurological differences that shape attention, learning, and other cognitive functions (e.g., dyslexia) (Kapp et al., 2013). Most research on neurodivergent children's interactive media use has focused on two neurotypes—autism and attention-deficit/hyperactivity disorder (ADHD). Though they may differ greatly in clinical presentation (e.g., communication, social interaction), autism and ADHD share several underlying characteristics (e.g., impulsivity, attention challenges) that may lead to convergence in neurodivergent young people's media and technology usage (Alper

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; AR, augmented reality; CCI, child-computer interaction; MR, mixed reality; VR, virtual reality; XR, extended reality.

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et al., 2025). For example, research indicates that video gaming and virtual worlds offer social, emotional, and creative opportunities for autistic preteens and those with ADHD that may be otherwise limited or inaccessible offline (Internet Matters, 2024; Ringland, 2019).

However, the immersive and data-intensive nature of XR technologies in the “metaverse” also poses dangers for young people, with neurodivergent children experiencing specific vulnerabilities. Concerns about XR risks for children includes online safety and privacy violations, sexual abuse, and physical side effects from overuse (e.g., Hinduja and Patchin, 2025). Neurodivergent young people may be more likely to encounter social, physical, and digital risks through their engagement with online games and XR technologies, such as problematic media use, sensory dysregulation, and behavioral challenges (Alper, 2023; Beyens, Valkenburg, & Piotrowski, 2018; Macmillan et al., 2022). XR technologies have generated much debate around their ethical implications, or potential desirable and undesirable consequences for the social contexts, actors, and principles and rules that govern their actions and activities (Michael et al., 2024). As emerging technologies are novel, their ethical concerns are inherently difficult to predict given their lack of wide domestication (Nordmann, 2007). There is a growing body of work on the ethical concerns of XR use by children (Hourcade et al., 2024; UNICEF, 2023), as well as ethics-focused research centering young people’s own perspectives, values, and perceived norms (Jin et al., 2024; Johnston et al., 2024).

Such work with young people on XR ethics has been conducted primarily with neurotypical children and teenagers. Though there may be considerable overlaps in the ethical issues raised by neurodivergent and neurotypical children (Alper, 2023), child-computer interaction (CCI) research has begun to recognize how the inclusion of disabled children’s perspectives leads to more comprehensive design considerations and novel research directions (Spiel et al., 2017). Neurodivergent adults have identified important ethical issues with XR such as negative psychological impacts of hyper-realism, social isolation risks, and a lack of platform safety protections (Creed et al., 2024). As such, we conducted an exploratory virtual video interview study with 21 [anonymized nationality] neurodivergent children ages 8–13, employing animated scenarios of speculative future XR uses as a discussion prompt (Jin et al., 2024), to identify these children’s views on the ethics, possibilities, and limitations of XR technologies. Our research focused on three key questions.

RQ1: What prior experiences do neurodivergent children have with XR technologies, and what are their views on the benefits and drawbacks of those experiences?

RQ2: What are neurodivergent children’s attitudes towards and opinions of potential future uses of XR technologies?

RQ3: What ethical concerns do neurodivergent children have about current and future applications of XR in their everyday lives?

This study contributes to the CCI community by surfacing the views of a population whose first-person accounts of novel technologies are underrepresented. While our results are preliminary given several limitations (e.g., small sample size), it is the first study to solicit neurodivergent children’s insights into the ethics of XR, conducting this work in a manner that respects their agency and presumes their competence, and building upon prior work that focuses on neurodivergent children’s experiences with and opinions of XR but not their ethical reflections (Newbutt et al., 2020). We found that neurodivergent children are able to identify and articulate ethical concerns regarding the future of XR, pros and cons of their prior XR use, and potential positive and negative effects of potential applications of XR. Our research offers informed perspectives into research on XR for children, guiding ethical principles, and design for neurodivergent children that considers their priorities, interests, and concerns.

2. Background

2.1. Potential benefits and drawbacks of children’s XR use

There are several possible benefits of XR among children across formal learning environments (e.g., classrooms) and informal learning spaces (e.g., museums, homes), as well as for their mental and physical health. With respect to learning, XR experiences may support skill-based learning, promote creativity and storytelling, increase information retention, and allow students to learn concepts in a dynamic manner (Dede et al., 2017; Yamada-Rice, 2021). XR can also have socioemotional benefits for children by enabling them to explore geographies and communities on local and global scales, and as a means of cultivating empathy for those with different backgrounds (McGivney, 2025; Muravevskaia & Gardner-McCune, 2023). Additionally, the active nature of XR use has the potential to facilitate gamified exercise and fitness experiences for children and families (Finkelstein et al., 2011; Sobel et al., 2017).

XR technologies also present a host of ethical complexities. They blur physical and digital experiences, recruiting the body (e.g., eye gaze, gestures) as part of the technological experience (i.e., biometrics). In addition to those noted earlier, short- and long-term concerns exist for child users, including the potentially socially isolating and addictive nature of immersive media consumption and intrusive personal data collection (Kaimara et al., 2022; UNICEF, 2023). Most XR devices are not intended to be used by those under age 13 (i.e., not designed for smaller head sizes and shorter interpupillary distances), yet children at ever younger ages are attracted to devices, apps, and platforms envisioned for older users (e.g., social media) (Cortesi et al., 2021). Companies are beginning to enable managed accounts for preteen XR users in which parents may limit content and approve social contacts (Meta, 2024). Concerns remain though regarding barriers to parental supervision during solo-use child VR play, age verification challenges, limited platform moderation, and a perceived lack of transparency in reporting safety and privacy violations (Allen, 2023).

2.2. Neurodivergent children and XR

One population for whom the ethics of XR technologies has not been fully explored, yet who may be greatly impacted, are neurodivergent children (Roberts et al., 2023; Salen Tekinbaş et al., 2023). In the U.S., current diagnosis rates for children aged 17 and under are approximately 11 % for ADHD and 3 % for autism (U.S. Department of Health and Human Services, 2024; Wang, Weng, et al., 2023). The neurodiversity paradigm recognizes that young autistic people and/or those with ADHD may possess certain cognitive strengths (e.g., pattern recognition, problem-solving), while also requiring additional support in important developmental areas (e.g., executive functioning) (Kapp et al., 2013). Neurodivergent people often have diverse sensory processing patterns that can result in negative physical and mental effects if their senses become dysregulated by environmental stimuli (e.g., anxiety, disrupted social interaction), including media that stimulate several senses simultaneously (Boyd, 2019; Harrison et al., 2019; Wasserman et al., 2019).

Studies on the benefits of educational and therapeutic XR interventions for neurodivergent children offer mixed results (Bailey et al., 2022; Mosher et al., 2022). Existing XR technologies, particularly VR, may possibly address a range of challenges for autistic users, such as communication difficulties, social interaction, and daily life skills in a uniquely engaging, personalized, and adaptive manner (Newbutt et al., 2020). VR systems that offer neurodivergent child users control over sensory inputs (e.g., volume, brightness) can support self-regulation (Boyd et al., 2019) and provide relief during periods of sensory discomfort (Boyd et al., 2022). Research indicates that autistic children ages 6–16 are interested in using VR for a range of purposes, including mood regulation, socializing, extending classroom learning, and visiting

places or engaging in activities before doing so in the “real world” to reduce uncertainty and increase confidence (Newbutt et al., 2020).

2.3. Methodological approaches to studying the ethics of emerging technology for neurodivergent children

As the field of XR is rapidly evolving, ethical concerns around its development, use, and applications intersect with ethical discourses around other emerging technologies impacting young people's lives, including AI and the “internet of things” (e.g., Durall Gazulla et al., 2025). One approach to addressing ethical concerns of quickly evolving technologies is for stakeholders (i.e., those likely to be impacted by emerging innovations) to provide on-going feedback to experts (Brey, 2017). Methods and approaches from the field of CCI lend themselves to such inquiry, as CCI focuses on the design, implementation, and evaluation of novel technologies used by children, employing participatory methods that directly engage young people to authentically represent their perspectives (Hourcade et al., 2018). Recent work has recruited children as partners in developing ethical guidelines for novel XR directions. In one study, researchers interviewed both children and their parents to identify ethical concerns around VR usage; children were found to be much more optimistic about VR than their parents, leading to potential tension and disagreement (Jin et al., 2024). In another project, researchers engaged teenagers as co-designers for ethical guidelines, uncovering key themes of data protection, autonomy, human flourishing, inclusivity and accessibility, and reduction of deceptive patterns in design (Johnston et al., 2024). Both projects cite the importance of involving their younger stakeholders, engaging their perspectives, and supporting their autonomy towards the creation of safe XR ecosystems.

With respect to neurodivergent children, it is important to center their views on the ethics of emerging technologies (Schmidt et al., 2023) and conduct said research in an ethical manner (Newbutt & Bradley, 2025). Autistic people and those with ADHD tend to be understood through a deficit-based frame by technology designers and less so as valuable partners in design research (Motti, 2019; Spiel et al., 2022). This study builds upon existing participatory HCI work with neurodivergent children (e.g., Boyd et al., 2019; Frauenberger et al., 2019; Hijab et al., 2024), but with a unique focus on engaging child stakeholders in exploring the ethical dimensions of current and future XR technologies. Several methodological considerations are necessary to enable autistic children and/or those with ADHD to take part in participatory CCI research, including conducting research in comfortable familiar environments, allowing children to discuss topics of interest, incorporating visual support (i.e., pictures, video) to supplement spoken instructions, flexible scheduling and timing of research for those requesting or needing extending time, and allowing trusted communication partners such as parents to help children share their “socio-communicative lifeworlds” (Sirota, 2010) during interviews by providing encouragement and direction.

3. Methods

Employing the methodological considerations discussed above, we conducted an interview study with 21 child participants with a parent-reported diagnosis of autism and/or ADHD to investigate neurodivergent children's experiences with and perspectives on the ethical uses of XR. In this section, we describe the research setting and background information about participants, our research procedure, the artifacts and instruments utilized in our study, our data analysis process, and limitations of our approach and execution of the study.

3.1. Setting and participants

We received IRB permission from [anonymized university; IRB # anonymized] as members of a research consortium studying child XR

ethics. Parent recruitment was digitally facilitated through social media, blog posts, emails to parent disability advocacy groups, and flyer distribution to local clinical centers serving autistic children. Adult participants were required to be residing in the [anonymized geographic] area, age 18 or older, comfortable communicating in spoken English, and the parent of a child aged 8-13-years-old with a diagnosis of autism and/or ADHD. Though ages 8 to 13 can be a wide age range in terms of digital skills and abilities, pre- and early adolescents commonly share media tastes and technology preferences (Rideout et al., 2022). In addition to these parameters, child participants were required to reliably communicate (verbally, typed, or through assistive speech technologies) in a 45-min Zoom interview (in which they could take breaks). Parent and child eligibility were confirmed via a screening email with parents.

Following eligibility confirmation, a consent form disclosing all study activities and research purposes was emailed to parents via DocuSign for digital signature. Parents received copies of their signed consent forms via email. A digital assent form was presented to child participants over several on-screen slides before the start of the virtual video interview and read aloud (unless child participants voiced a preference to read the assent form themselves). Children provided assent verbally (e.g., “Yes”; “OK”) and/or physically (i.e., thumbs up sign). Following a Universal Design for Learning approach (CAST, 2024), additional accessibility considerations for conducting virtual research with neurodivergent child populations were incorporated, including enabling live closed captioning on the video call if requested and including visual representations alongside on-screen text to support comprehension. All child participants used oral speech as their primary mode of communication.

We recruited 21 child participants and their parents. The average age of parents was 43.57 (SD = 6.42), consisting of 20 parents identifying as female and one as gender non-binary. In terms of race/ethnicity, 66.66 % identified as White/Caucasian (n = 14) and 33.33 % (n = 7) as non-White (including those identifying with one or more non-White racial/ethnic identities). Non-White racial/ethnic identities in the parent sample included Black/African American (n = 4), Hispanic/Latinx (n = 3), and Indigenous (n = 1). A little over half of parents (57.14 %; n = 12) possessed a graduate degree, followed by bachelor's degree (4 years) (28.57 %, n = 6) and high school diploma (14.28 %, n = 3). Most parents (66.66 %, n = 14) reported an annual household income of \$100,000 or more. Notably, the majority of parents (52.38 %, n = 11) themselves had a neurodivergent diagnosis or believed strongly that they would qualify for a diagnosis, including autism (n = 7), ADHD (n = 7), and attention deficit disorder (ADD) (n = 4).

Child participants had an average age of 10.28 (SD = 1.79) and were comprised of 4 females, 13 males, and 4 children whom parents identified as transgender (e.g., “Trans-F to M”; “Transfemale”). Of these, 57.14 % (n = 12) were identified as White and 42.85 % (n = 9) as non-White (including those identified with one or more non-White racial/ethnic identities). Non-White racial/ethnic identities in the child sample included Black/African American (n = 5), Hispanic/Latinx (n = 5), and Indigenous (n = 1). Children were mostly evenly split between those with a diagnosis of autism (without ADHD) (38.09 %, n = 8), those with a diagnosis of ADHD (without autism) (33.33 %, n = 7), and those with dual diagnoses of autism and ADHD (28.57 %, n = 6). Two-thirds of children had a diagnosis of autism (66.66 %, n = 14), and slightly less with ADHD (61.90 %, n = 13). Child participants had additional diagnoses, with the most common being anxiety (42.85 %, n = 9), depression (19.04 %, n = 4), and sensory processing disorder (19.04 %, n = 4). Other diagnoses included ADD, avoidant/restrictive food intake disorder, epilepsy, intellectual disability, sleep disorder, speech/language disorder, and obsessive-compulsive disorder.

3.2. Procedure

This study employed multiple methods to understand neurodivergent children's XR experiences and perspectives. To protect

privacy and minimize discomfort, child and adult participants were told that they had the right to decline to answer any question or end the study at any time. Prior to the child interviews, parents filled out a family information sheet via Qualtrics (e.g., household income, parent educational background). Form completion was estimated to take approximately 15 min. Parents were also asked to provide information about the child that would be helpful for offering accommodations during the interview (e.g., communication preferences, behavior and attention difficulties). Following completion, the lead author scheduled virtual Zoom interviews at a time convenient for parents and optimal for the neurodivergent child's active participation in the interview (e.g., not immediately after school when the child needed a break). Interviews were estimated to take 45 min, but ranged from approximately 17 to 59 min given the varied ages, communicative capabilities, and enthusiasm of the child participants. All research was conducted from March to October 2024.

Virtual study activities with neurodivergent children were conducted by the lead author over a secure university-sponsored Zoom account. It was communicated to parents prior to the interview that they should select a space in the home that was quiet, private, and where other family members would not be present, and to ensure that they had a stable internet connection on their selected device (e.g., laptop, tablet, smartphone). While all parents set up the Zoom call for their child, they varied in the level of communication support and degree of physical copresence provided during the child interview. Some only appeared on-screen at the start of the call and some sat next to their child throughout. Other parents more closely scaffolded the interview for their child relative to their needs for behavioral, emotional, cognitive, and communication support (for example, by rewording the question or reminding them of past media use).

The interview consisted of three parts. First, children were asked about their overall media and technology preferences, as well as if they had used VR, AR, and MR before, and to discuss their likes and dislikes about any experiences. To aid comprehension, each XR type was explained to child participants and presented with a photograph depicting its use by young people (e.g., MR as "like interacting with screens on a wall"). Second, children were asked to watch two short 1-min animated videos about children using XR in the future on a topic of their choosing from among the following three: education, family, or health. After viewing each video, child participants answered 3 Likert-scale questions designed to explore perceived pros and cons of XR as demonstrated by the scenarios. Lastly, children were engaged in a discussion about the scenarios they viewed, as well as their thoughts on the ethics of XR use by "kids like you," which was left purposefully open-ended (i.e., did not name autism or ADHD).

Following the Zoom interview, an automated transcript was generated and corrected by study team members using an audio recording. The interviewer also wrote memos following each interview to contextualize the conversation and maintained a reflective log over the course of the study about emerging themes and patterns. A spreadsheet was created of quantitative data generated by the child interviews. Data was anonymized and kept secure using a university-sponsored storage account only accessible to the research team. Each adult and child research participant received a unique numerical identifier associated with their data. Qualtrics links were also unique to each parent. Participant responses were digitally stored separately from names and email addresses. Each parent who filled out the information form and whose child completed the interview received a \$75 Amazon e-gift card as compensation.

3.3. Artifacts and instrumentation

3.3.1. Child reported media preferences

At the start of the virtual interview, children were asked to rank their first, second, and third favored media types from a list of 9 options based on Common Sense Media's media census of children ages 8–18 (e.g.,

playing mobile games, watching TV) (Rideout et al., 2022).

3.3.2. XR scenarios and survey

We employed animated video scenarios of speculative future XR use by children. The videos were created and previously fielded by Jin and colleagues (2024) in their study of children and caregivers' ethical concerns regarding children's VR usage (video screenshots appear in Jin et al., 2024). Jin et al. made their videos freely available on YouTube, which we embedded into our Zoom interview slides. We selected the scenarios for several reasons, including their relevance to children's lives, their short length, the potential to compare results across studies, and the accessibility benefits for autistic children of using concrete visual examples to explain complex abstract concepts. Each video scenario condition (education, family, and health) had a utopian and dystopian version, highlighting potential benefits and risks of XR. The videos were not labeled as utopian or dystopian, and child participants were allowed to interpret the scenarios' ethical implications. The plots of the scenarios are summarized as follows by Jin et al. (2024).

- Education Utopian: VR experiences augmenting an afterschool STEM program.
- Education Dystopian: VR shifts to education entirely within a virtual school setting.
- Family Utopian: Family engaging together in VR game play.
- Family Dystopian: Family members individually immersed in separate VR experiences while together physically.
- Health Utopian: Use of VR for distraction during children's medical MRI procedures.
- Health Dystopian: Children using VR to cope with pain and avoid physical exertion in post-medical procedures.

After watching each video from their selected theme, children answered three survey questions for each scenario: 1) Would you want to use XR as shown in this video? 2) Do you think using XR as shown in this video might create a problem in your life? and 3) Do you think using XR as shown in this video would make your life better? We employed Jin et al. (2024)'s 3-item Likert-style scale to measure children's responses: *no*, *a little*, *a lot*. We adapted the scale to include a visual representation of each item to support comprehension for neurodivergent learners (Fig. 1). Children were also asked to explain their answers to each question.

3.3.3. Semi-Structured XR ethics interview

Children were asked four concluding questions about the use of XR, which led to additional follow up questions for participants able to provide further insights (e.g., comparisons to other media forms): 1) What did you think about the use of XR in these videos? 2) What kinds of problems might XR create for kids like you? 3) Who should make the rules about what kinds of XR is okay for kids like you? and 4) Is there anything else that you want to tell me about XR for kids like you?

3.4. Data analysis

To answer our three research questions, we analyzed quantitative and qualitative data from the study. For the scenario surveys, we converted the Likert-style scale responses into a numerical format, where we assigned weights ranging from 0 to 2 for responses (e.g., *no* to *a lot*). We subsequently performed a descriptive analysis of the data, statistically computing the mean, median, and standard deviation to identify consistency and variation within the dataset. Our focus on children's self-report reflects recent ethical shifts in research on neurodivergence (Pellicano & Stears, 2011) and responding to an overreliance on adult proxies in participatory CCI research with autistic children (Hijab et al., 2024).

With respect to qualitative data gathered during the child interviews, we applied thematic analysis (Guest et al., 2012; Saldaña, 2016), which

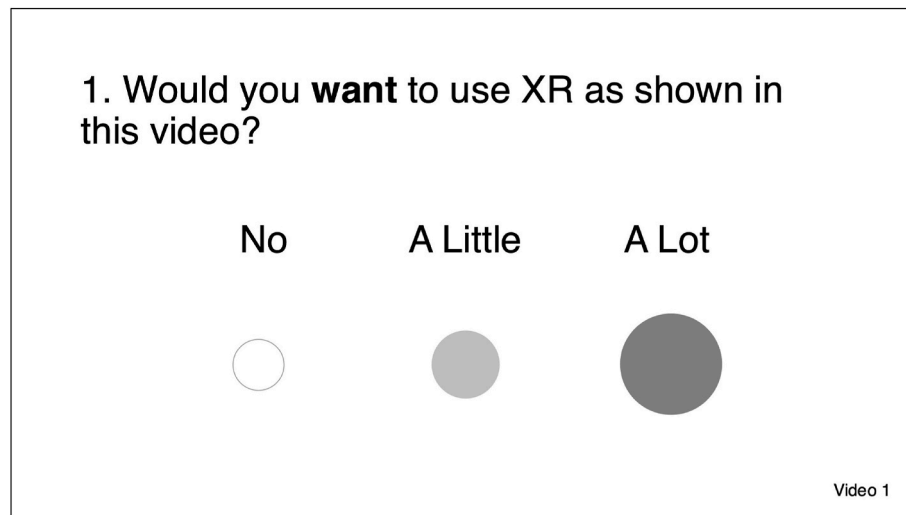


Fig. 1. Likert-style scale with visual representation.

allowed for patterns of meaning to emerge from the data. Drawing upon our commitment to the use of critical disability studies frameworks in HCI (Hofmann et al., 2020), we recognize disabled and non-disabled researchers' active roles in knowledge production and incorporate our reflections throughout the analysis process. For example, members of our team have varying relationships to neurodivergent diagnosis, including diagnoses of autism and ADHD, which informed non-pathologizing interpretations of child participants' media practices and preferences.¹ We utilized a combination of inductive and deductive coding (Charmaz, 1983; Fereday & Muir-Cochrane, 2006) during our iterative, evolving, and collaborative analytic process (Strauss & Corbin, 1998). Three research team members conducted a round of open coding of the child interview data, guided by the research questions. Following coding, the research team read the codes, commented on others' codes, and met to discuss overlaps and divergences in the interpretations, yielding a final set of themes and subthemes.

3.5. Limitations

In this study, we utilized scenario instruments created by other researchers. This approach was beneficial, as it allows for replication and comparison across studies. However, we could not edit or alter the animated stimuli, which may have created access issues for neurodivergent children in our study. For example, we did not insert additional narration (i.e., image description) into the recorded audio that could have supported accessibility, provided clarity, and improved comprehension of the ethical questions raised by the scenarios for those with intellectual disabilities (e.g., social cues regarding the facial expressions of the animated characters). As we did not ask children to imagine future scenarios of their own, the study may also be limited by the moral issues and contexts of XR usage that it explores. We did not evaluate or measure the sensory sensitivities of our child sample, so we are unable to discuss the extent to which their specific abilities reflect how neurodivergent children interact with multi-sensory XR experiences (Boyd, 2019). It also would have been beneficial to find out not

just if a child had used XR before, but also how regularly they currently used it and the last time they had used certain forms (e.g., VR vs. AR).

In addition, our study sample, though diverse in several respects, is not representative of all neurodivergent young people. Most children came from highly resourced families, with the majority of parents reporting high incomes and graduate-level education. This may have influenced several factors shaping children's experiences with XR, including the amount of physical space within their homes with which to safely engage with the technology. None of the children were non- or minimally speaking and none required augmentative and alternative communication (AAC) to participate in the interview, which limits the representativeness of the autistic sample, as around 30 % have limited or no use of embodied oral speech (Rose et al., 2016). The child population skewed slightly more White than non-White, though our sample is more racially diverse than most research on neurodivergent child populations. We respected the agency of autistic children by letting them select a video scenario topic of their choosing. However, because less children chose the health scenario ($n = 3$) than the education or family scenarios, we do not have equal comparison groups in our analyses; thus, our ability to draw conclusions from the health sample and across conditions is constrained. Some discussion questions were also skipped over at the end of the interview if the child's attention span was limited.

4. Results

As our study employed mixed methods, we offer both quantitative and qualitative analyses of our findings to illustrate how neurodivergent children use and understand the present and future of XR and its ethical implications. These results are preliminary, however, given our study's skew in sample size, low sample size, and research instrument limitations. We first provide an overview of our quantitative findings then delve into our qualitative results (identifying children by anonymized number) in the following three areas: neurodivergent children's XR experiences and preferences (RQ1), their attitudes towards potential uses of XR technologies via their reflections on future scenarios (RQ2), and the broader ethical concerns they raise regarding XR (RQ3).

4.1. Neurodivergent children's XR experiences and preferences (RQ1)

In terms of neurodivergent children's self-reported overall media preferences, games were central to their media diet; 95.23 % ($n = 20$) said gaming (either playing video games on a console or computer, playing mobile games, or using virtual reality) was their first or second favorite type of media activity. This was followed by video content, with

¹ The neurodiversity of our team shaped our analysis in several respects. For example, for some neurodivergent team members, the act of coding could be a joyful process when encountering neurodivergent children's self-narration, elicit empathy for children with communication challenges, and cause some grief over children being supported in interviews in ways that might not have been as available to them as neurodivergent children. Variations by neurotype also potentially led to varying degrees of detail in subtheme generation and organization.

52.38 % (n = 11) reporting either watching online videos or watching TV as their first or second favorite media activity. The majority of child participants had engaged in prior XR use; only 3 participants (14.29 %) had never used XR before. Most reported that they had used VR (76.19 %, n = 16), and less so AR (57.14 %, n = 12) and MR (57.14 %, n = 12). Our thematic analysis of neurodivergent children's XR experiences, drawn from our interviews, is organized below around three main themes: prior experiences, as well as perceived benefits and perceived drawbacks (Table 2).

4.1.1. Prior experiences

Neurodivergent children had engaged with XR across a variety of contexts and environments, primarily for the purpose of gaming. In terms of VR, children recalled using it at a friend or family member's house with that individual's headset, at home with a family-owned headset, and at an arcade or amusement park. Children's prior usage of AR consisted of using it on a parent's phone (mainly the app Pokémon Go) or on a handheld mobile video game console, doing so at home, in the car, and at a playground. Prior experiences of MR were limited to informal education settings (e.g., museum, aquarium, arcade, autism therapy center).

4.1.2. Perceived benefits

Neurodivergent children identified several positive benefits of their past XR use. They recalled *pleasurable feelings of immersion and interactivity* within hybrid physical/digital worlds, mostly in VR but also AR and MR to some extent. For example, children thought it was cool that XR could "trick" (C6) your brain into thinking you were somewhere else and that you could "pop on the headset and I'm in a whole new world" (C11). Moreover, children enjoyed the *full body interactivity* enabled by XR. Compared to stationary video games, "sometimes VR is better if you want to exercise a bit or just move around" (C8). AR and MR provided additional satisfaction due to a wider range of movement. C11 noted that a benefit of MR was more mobility: "I found it really nice. It's not like virtual reality because you have a headset on all the time. When it's on the floor, you just step on a screen and run around." They found XR to be *fun and enjoyable*, both for recreational purposes and for learning. C14 liked simulating a convenience store worker in a job simulation VR game because "you can do stuff that you wish you could do, but not actually do in real life." Children also noted engaged learning at science museums though MR installations including a plague simulation (C1) and an interactive physics exhibit with "ping pongs [that] will go everywhere [...] it's really fun" (C11).

Interpersonally, neurodivergent children identified *socializing with friends and family in an embodied yet virtual manner* as a benefit of VR. C11 enjoyed playing the video game Royale High in the Roblox app on the Meta Quest with friends, as an extension of their online play: "I get to meet all my virtual reality friends and I could see what they're doing." VR also was enjoyed by neurodivergent children due to the opportunity for *vicarious play* when viewing the screen of another co-located player. Owing to physical discomfort from wearing the VR headset, C20 found it more enjoyable to watch the video cast of his friend's VR game play on their computer screen than to play himself: "We got to see what he was doing on the computer [...] I wanna see what the people are doing instead of playing the game."

4.1.3. Perceived drawbacks

Neurodivergent children noted various drawbacks of their prior uses of XR. Many did not like having to *rely on parents to facilitate access, connectivity, and use*, particularly for Pokémon Go. C10 discussed children's limited geographic mobility when playing location-based games independently: "If there's a really good thing really far away from me, and I really want to do a giant gym battle or a legendary Pokémon, I can't get there because if I'm just playing in my house." Some bemoaned *technological issues* that made their experiences less seamless. C18 had tried to play Pokémon Go but had access challenges: "It told me I have to

make a new account. When I tried to, [it was] when [we were] driving. The phone was about to die, so I had to give it back to my mom." Other children identified the *necessity of multiple headsets for social play with co-located others* as a limitation of VR. C19 thought it would be nice to have two headsets so he could co-play with his mom, as they already frequently game together. Children discussed significant *variability in the quality of XR content* as limiting the technology's appeal. For example, C7 thought AR and Pokémon Go "was kind of cool. But it's nothing compared to VR" due to the complexity of VR games.

Those neurodivergent children who had used XR also reported experiencing several *negative physical and psychological effects*. C12 recognized that "usually when I play VR for a long period of time, it makes my head hurt." As mentioned earlier, C20 found wearing the VR headset to be "very uncomfortable [...] The little straps that go around your head ... the back of my head got very, very itchy." For C21, VR induced a fear-based reaction that the child could recall with vivid and specific detail:

I was playing Penguin Paradise, and then it was [the] freeze tag [game mode]. The game was already on. I put it on, and then I looked down. The floor was made out of ice glass, like you could see through. I was kind of scared. [...] I was so high in the game. So, I immediately took it off and gave it to my brother.

In sum, neurodivergent children reported a wide range of prior experiences with XR, positive and negative, leading some to abandon the technology and others to re-evaluate their use.

4.2. XR scenario reflections (RQ2)

Children next watched scenarios and responded to survey questions to generate insights into how they perceived future usage of XR (and specifically the applications of VR depicted in the videos). Overall, children held more positive attitudes towards the utopian scenarios than their dystopian counterparts, and found the utopian scenarios to be less problematic and have more potential to improve their lives (Table 1). Across all scenarios, children found the utopian healthcare scenario to be the most desirable (M = 2.00, SD = 0.00), least problem causing (M = 0.00, SD = 0.00), and have the most potential to better their lives (M = 1.33, SD = 0.58). The dystopian healthcare scenario elicited the most concern about negative effects (M = 1.67, SD = 0.58) and was considered the least likely to improve children's lives (M = 0.00, SD = 0.00).²

Children had more ambiguous attitudes toward the scenarios on education and family than the healthcare scenarios. Specifically, on average children did not see these dystopian scenarios as more likely to cause a problem in their lives than the utopian scenarios. However, there was wide variation among children, especially concerning the dystopian family scenario in which a boy plays Minecraft with his friends while ignoring his mother (SD = 0.97). Children did not think that either the utopian (M = 0.56, SD = 0.53) or dystopian (M = 0.67, SD = 0.71) education scenarios would cause a problem in their lives, despite the dystopian scenario visually (though not verbally) suggesting a child being overstimulated after a full day in VR school. In addition, children wanted to use as XR as shown in both the utopian (M = 1.67, SD = 0.50) and dystopian (M = 1.33, SD = 0.71) family scenarios, and thought that both the utopian (M = 1.33, SD = 0.50) and dystopian (M = 1.22, SD = 0.83) versions would better their lives. The qualitative results provide further insights into our quantitative findings, specifically the rationale behind children's positive and negative attitudes towards the fictional renderings (Table 3).

4.2.1. Positive attitudes

Neurodivergent children reacted positively to the scenarios in various respects. They liked the idea of using XR to *maintain close*

² It should be noted that the healthcare condition sample was considerably smaller (n = 3) than each of the other two groups (n = 9).

Table 1
XR scenario survey results.

Area		Education		Family		Healthcare	
Participants		n = 9		n = 9		n = 3	
Scenario		Utopian: VR experiences augment learning	Dystopian: VR experience replace in-person learning	Utopian: Joint family VR engagement	Dystopian: Family separate VR engagement	Utopian: Help child patients during medical procedures	Dystopian: Children use VR to escape pain post-medical procedure
Would you want to use XR as shown in this video?	M	1.28	0.94	1.67	1.33	2.00	1.00
	Mdn	1.5	1	2	1	2	1
	SD	0.83	0.81	0.50	0.71	0.00	1.00
Do you think using XR as shown in this video might create a problem in your life?	M	0.56	0.67	0.33	0.78	0.00	1.67
	Mdn	1	1	0	0	0	2
	SD	0.53	0.71	0.50	0.97	0.00	0.58
Do you think using XR as shown in this video would make your life better ?	M	1.13	0.89	1.33	1.22	1.33	0.00
	Mdn	1	1	1	1	1	0
	SD	0.64	0.60	0.50	0.83	0.58	0.00

Table 2
Neurodivergent Children's perceived benefits and drawbacks of XR based on prior XR experience.

Themes	Subthemes
Perceived Benefits	Pleasurable feelings of immersion and interactivity Full body interactivity Fun and enjoyment Socializing in an embodied yet virtual manner Vicarious play
Perceived Drawbacks	Reliance on parents to facilitate access, connectivity, and use Technology issues Need for multiple headsets for social play with co-located others Variability in content quality Negative physical and psychological effects (e.g., fright)

Table 3
Neurodivergent Children's rationales for positive and negative attitudes towards XR scenarios.

Themes	Subthemes
Rationales for Positive Attitudes	Remote relationship maintenance in an embodied manner Social play with co-located others Potential for immersive and embodied play/learning Escape from unpleasurable aspects of physical reality
Rationales for Negative Attitudes	Displacement of rewarding in-person social interactions Negative physical and psychological effects (e.g., photosensitivity) Limitations on users' social, spatial, or temporal awareness

relationships from a distance in an embodied manner. This included with family and friends, and at distances near and far. C1 was excited by the idea of VR play with a friend who lives in Canada that she met at a camp for other transgender children, building on prior social gaming together on Discord. Regarding VR game play with family living in another state, C11 thought “it would be really fun to do it with people who are far away that are close to me.” Relatedly, some also thought that XR could provide an engaging opportunity for *social play with co-located others*. C20 was interested in family co-play with VR after viewing the Family Dystopian scenario: “When Colby went to teleport into Minecraft [...] what if he [...] asked his mom or dad to spend time with him and play with him.”

In addition to these social dimensions, children were interested in XR's *potential for immersive and embodied play and learning*. With respect

to recreational play, as depicted in the Family Dystopian scenario, C19 said that they would like to play Super Mario on VR (versus on a console), because “I would be Mario. [...] I always thought Mario was real, and I still do. [Mario in VR] would make me believe him even more.” As it pertained to education, C7 found learning in the Education scenarios (both Utopian and Dystopian) to be “fun,” “active,” and “a really cool way to learn.” C5 saw value in moving while learning with screens and not “only your fingers.” When asked follow-up questions regarding comparisons between VR learning and remote learning during the COVID-19 pandemic (which nearly all children had experienced), neurodivergent children considered VR to be superior. C8 thought that VR learning offered a more participatory and active environment than classroom teaching (“that is my style of learning [...] so it would help me learn a lot”) and superior to Zoom school during the COVID-19 pandemic because VR offered “more hands-on learning rather than just sitting there.”

Additionally, neurodivergent children found it appealing that XR might offer an *escape from unpleasurable aspects of physical reality*. Children noted the appeal of both the Health Utopian and Dystopian scenarios, depicting children being distracted from an unpleasant medical encounter by VR. Noted C14, “you wouldn't have to know what was happening. You would just be watching a video cartoon without knowing. [...] so you don't have to see the procedure.” Interestingly, the majority of children who selected the Education scenarios reported that VR school appealed to them because there would be no need to get ready for school in the morning and they could avoid a transition that many found difficult. If they went to school in VR, C8 imagined that “I would not have to wake up as early. I like to sleep. So that would be an upside.” Though the stakes of displeasure were quite different in the Health and Education scenarios, the idea of avoiding physical reality to some extent appealed to neurodivergent children.

4.2.2. Negative attitudes

In terms of downsides though, the scenarios elicited several negative reactions from neurodivergent children. Many thought that the scenarios suggested the possibility of XR *displacing rewarding in-person social interactions*. C6 said that VR could “hinder a connection” with family if replacing in-person visits, while C8 felt that “you're not being there socially” when with a person's VR avatar. Neurodivergent children though recognized their own personal vulnerabilities to the scenarios with respect to social displacement effects. “I might be on it too much,” reported C10, “If it was a beautiful day outside [and] all my friends were outside to play, I might be sitting inside playing video games and forget about everything, and only have fun on video games and not anywhere else in the world.” C11 was concerned that “if you get addicted [to VR], [...] then you won't really be able to talk with real life friends.”

Neurodivergent children were concerned about several potential *negative physical and psychological effects* from XR based on the scenarios. C16 mentioned physical strain from the weight of VR headsets on a child's head ("[It's] a giant piece of bulky metal. [...] Your face could get really, really heavy.") Phobias and nightmares were key psychological concerns. C21, who had an aforementioned prior fear-based reaction to VR, worried about adverse psychological reactions ("When I was little, I used to get all sorts of dreams. So, I think that would probably cause a bad dream at night.") as well as the impact of XR "if you have heart conditions [...] because it might be scary." Ocular and vision effects were a common fear, relative to time spent using VR. Said C10, "I don't feel it'd be good putting the headset on for a whole hour. Staring through the headset playing a game." C6 noted that they used blue light glasses for long game play on computer, and was curious if there was a VR equivalent. Neurological effects were also regularly mentioned, including headaches (C11: "when there's a screen glued right into your eyes, you'll get a lot of headaches") and photosensitivity. C16 was concerned about flashing lights in VR causing seizures: "XR may be a little too stressful for some children. [...] The lights from the set may burn [and] it may hurt their eyes. Especially if the child has epilepsy."

In addition, children thought that the scenarios highlighted XR *limiting user awareness*, be it social, spatial, or temporal awareness. Echoing the above concerns about trauma, C16 said that it would be physically jarring if someone removed another's VR headset suddenly without prior notice: "People can just take the headset off [and] away from you." Other children noted that VR could limit being aware of people around you. C11 was concerned that with individual family members using VR separately, "everyone will be stuck in their little virtual lives that they won't be able to tell that something's going on [around them]." Physical risks of limited spatial awareness were also mentioned relative to AR and VR (C16: "[Kids] might get really hurt by using the XR because they can't pay attention to where they're actually looking, so they may fall down.") Some children mentioned experiencing time blindness, or a common experience among neurodivergent people in which one is unable to sense the passage of time or estimate how long an activity will take. Due to time blindness, it was easy for neurodivergent children to lose track of time with media, as C11 explained, "When you have kids like me, we always get off track with time, so we may be on [VR] for days or whatever and we can't tell." To accommodate this, C11 would "always try to check the time, or I'll have a little alarm, or my mom will call me down." Overall, the utopian and dystopian scenarios viewed by the child participants enabled them to predict a range of both possible and negative effects of XR on children.

4.3. Neurodivergent children's ethical concerns regarding XR (RQ3)

Finally, beyond the specific scenarios, neurodivergent children highlighted a wide range of ethical concerns with XR in its current and future iterations, spanning issues that concerned technology, political dimensions, and health and well-being (Table 4).

Table 4
Neurodivergent Children's ethical concerns regarding XR.

Themes	Subthemes
Technical	Data collection, transparency, and privacy Platform design
Political	Just and unjust regulation Degree of adult oversight Digital and social inequalities Agency and specific needs of neurodivergent children
Well-Being and Health	Cyberbullying Social isolation Replacement of face-to-face interaction Negative mental and physical effects (e.g., addiction)

4.3.1. Technical

Several neurodivergent children were attentive to ethics of *data collection, transparency, and privacy*. With respect to corporations, they were unclear how targeted advertising worked in VR (C1) and were skeptical that XR companies would make design choices that could reduce their profits, particularly industry self-regulation limiting player data collection and monetization (C6). Regarding educational institutions, C7, who seemed to highly value children's autonomy, argued that if school was blocking or tracking a child's game play on a VR device, that would be an "invasion of privacy." Neurodivergent child participants also raised concerns about the ethics of using *platform design* to mitigate child risks. C16 noted that user-generated games on Roblox with flashing lights sometimes have warnings, and that would be even more important in VR: "It says 'warning' on the description [in Roblox] like, 'Warning: This game has flashing light. Do not play. I have epileptic seizures.'" C16 was unsure if this disclaimer was optional or mandatory for XR game developers: "I'm not sure if they make them put it on, or if they decide to put it on, because you can decide whether your game has flashing lights or not."

C6 thought that there were pros and cons to XR platforms warning child users that they had been using the technology for too long, seeing as "that's the person's choice." However, C6 also noted that VR has many games at setup and thought that there should be fewer choices for young kids at first. Several children thought it was important for XR platforms to institute age restrictions, including limiting child-inappropriate content (e.g., too scary or violent). C16 felt the need for "parents or manufacturers [...] to tamper with the settings so that they'd only show something that's kid friendly," including turning off web search functionality and limiting access to certain games. C12 thought that platforms should make content maturity level clear to child users, as with movies and video games ("If you can't really play this game if you're a certain age [or if something is] really mature.") C14 additionally noted the physical dangers of XR and the need for clear in-game boundaries ("They should make sure there is the border that shows [the player] when they're actually gonna hit someone. Something just to keep them safe.")

4.3.2. Political

With respect to political issues of agency, power, and fairness, neurodivergent children made note of the potential for *political actors to regulate XR in just and unjust ways*. When asked who should make the rules about XR for kids, C1 responded "not Donald Trump," which was unsurprising given the child's status as transgender, the family's comfort discussing politics with the child, and their liberal views. Regarding executive power, C13 thought that "the president" should decide what kind of XR is appropriate for kids to use "unless the person is a bad president." With respect to policy, C6 would consider there being a warning on VR in "the same way that there was the federally mandated cigarette warning," given the potential addictive qualities of immersive VR games.

On a more direct level, neurodivergent children discussed how the micro-politics of *immediate adult oversight* over their XR use brought ethical complexities. They identified tensions between adults and children in supervising, managing, and regulating child XR use at home and in school, complicated by the affordances of the technology (e.g., parental controls). For instance, C13 thought that parents—not kids—should make the rules about what kinds of XR is appropriate for kids "because they're the owner of the kids!" Alternatively, C15 thought that child XR rules should be set collaboratively by children and parents ("me [and] my mom"), similar to how they had discussed together which Roblox games were appropriate for the child to play. Though C10 said that parents should make rules about XR, they felt that they could self-manage their own time spent with VR ("I may get bored playing Legos or something [...] so a little time [with VR] is okay. I don't want to spend too much time.")

Children were a bit more wary of teachers and administrators

intervening in their use of school-issued VR headsets and VR use for educational purposes in and out of school, tied to concerns about school staff not being properly trained in how to ethically engage with neurodivergent children. C7 thought it was fair for XR to be “[blocked] during school hours [but ...] I wouldn’t want adults to be always watching over our backs [...] being a monitor that monitors every single situation.” C14 had a great deal to say about the ethical implications of in-school suspension within a school existing only in VR, and the power of symbolic gestures even outside of physical reality. They discussed the challenges of virtually disciplining a child who attacked others in VR (“I imagine detention is just like being stuck inside a room, but you can still leave it whenever you want.”), questioned if the punishment should be the same as if that student had physically assaulted someone (e.g., throwing a trash can at a teacher in VR), and wondered how a parent would react to their child’s suspension from VR school (“How do you get expelled from a school that does not even exist?”).

Neurodivergent children also were attentive to how inequality and inaccessibility might be furthered by XR. They noticed that XR could widen or lessen *digital and social inequalities*. Some, like C8, identified equity benefits, like VR making field trips in some form possible for less resourced children (“It really takes the school resources and makes it a little easier. You don’t have to pay for the trip to DC.”) C14, however, saw hidden costs, in that a school taking VR field trips “must be rich because they can spend on so many students to get them so many VR [headsets].” In addition, C16 envisioned students attending VR school remotely not having equal opportunities depending on the physical space in their home (“You actually have to walk around. And I live in a really small place. And it’s gonna be kind of hard because you would bump into walls.”) and their digital skill level (“Some people may consider it to be a little too complicated to be used if they never used a headset before.”)

Another recurring theme was recognizing the *agency and specific needs of neurodivergent children* in XR use and design. C7 claimed that autistic young people are strong (“you better not piss us off”) while recognizing their greater likelihood of being targeted online. They thought it was important in the long term for autistic children like them, with difficulty navigating social interactions online, to learn how to handle challenging situations without adult intervention (“We need to know when something is wrong. And if we don’t know when something is wrong, then it’s basically digging us our own grave.”) C11 discussed how it can be hard for neurodivergent kids to employ strategies and features to protect their privacy and safety: “In Roblox, [...] I see a lot of people being like, ‘Oh, here’s my phone number,’ or ‘Here’s my age,’ or ‘Here’s my real name.’ It’s not really the best.” They believed that one solution was for neurodivergent people to be involved in XR development from the outset, noting that “someone who has ADHD or someone who has autism should make the rules [about XR use for neurodivergent youth because they] are in the same mindset.”

4.3.3. Well-being and health

Ethical concerns regarding the impact of XR on health and well-being were commonly raised by neurodivergent children. They talked about how *cyberbullying* might be perpetrated through XR in ways similar to and different from other media. For instance, compared to text-based harassment in the Roblox chat, C11 saw the potential for VR abuse to feel more vivid, similar to an experience in the physical world but exacerbated by sensory sensitivities: “If there’s people yelling at you in the virtual game [...], it feels like an actual person just being up in your face” Neurodivergent children also brought up *social isolation* as an ethical concern of XR. Though several noted that they enjoyed playing games by themselves, they also thought inherently that “using [VR] screens does isolate you” (C8), especially compared to AR and MR, in which the eyes are not covered (C6). They saw limited potential for XR to fully *replace face-to-face interaction*, including in-person and live mediated interactions. Setting aside issues with lag and bandwidth limitations in VR (which children raised), they talked about both the

superiority of being physically in person and the inferiority of being virtually present. “I just don’t see how virtual reality can be really related to actual reality,” said C9, “I feel like going to a real school would be much better.” C12 talked about the positives of in-person learning such as “[doing] work on paper and stuff” and “[going] outside during school.” C19 found VR play with others to be “kind of like, too AI-ish [compared to] the Wii or the console. [...] I’m old-fashioned!”

Lastly, children diagnosed with autism and/or ADHD expressed significant concern about a range of *negative mental and physical effects* that could hypothetically be caused by XR, including problematic media use, addiction, attention issues, and sleep impacts. Talk about potential addiction to VR was common among child participants, sometimes reflecting their personal vulnerabilities. C10 admitted that VR might cause children to “be too addicted to screens, to which I already am.” With excessive use, it “may be hard to focus on anything else. Just focused on playing the game. Always talk about it,” said C10, alluding perhaps to autistic children with highly focused interests. Age was a qualifier mentioned by several children, in that younger children were more susceptible to VR addiction. C6 thought that VR headsets “could behave almost like a drug” for early elementary-age children and was worried about younger neurodivergent kids having more behavioral issues when transitioning away from VR use, as he himself had experienced anger when getting his iPad taken away when he was younger. In addition, C6 had reportedly heard about people sleeping in VR headsets or using them for 3–4 h at a time, which “has to mess with your brain.” Neurodivergent children were self-reflexive about VR’s potential negative health effects, particularly in light of their own self-stated susceptibilities.

5. Discussion

In our study, we found neurodivergent children to be highly attentive to the potential ethical complexities of XR, based on both their prior experiences with the technology and fictional scenarios of future use. Neurodivergent children had some difficulty identifying dystopian elements of XR futures, particularly when there were other appealing aspects of the scenarios (e.g., not having to attend school, playing with friends) and when negative consequences were not made fully explicit. Despite these challenges, neurodivergent children were able to identify both positive and negative impacts of XR in the future, as well as a range of ethical concerns spanning technological, political, and health-related dimensions. Neurodivergent children also acknowledged a need for measured intervention and regulation (i.e., parents, government, platforms) to prevent child misuse and overuse of XR. Below, we discuss our findings relative to prior work on youth perspectives on XR ethics with neurotypical child populations, as well as design, ethical, and research implications.

5.1. Considering and comparing neurotypical and neurodivergent child XR perspectives

We found both similarities and differences between neurotypical and neurodivergent children regarding their experiences with and reflections on XR, with several possible explanations for any discrepancies. Compared to same-age neurotypical children in prior work, neurodivergent children in our study reported being more likely to have tried VR before (76.19 % vs. 44.78 %) (Jin et al., 2024). Gaps between the two populations could be an indicator of the high overall income level of the child sample in this study, but it also may reflect neurodivergent children’s strong interests in gaming (Mazurek & Engelhardt, 2013). In interviews, neurodivergent children drew on their overall experiences with gaming and XR gaming in particular when considering XR futures, particularly as they had far less first-hand experience with XR in non-recreational contexts (e.g., school, therapy).

We found that neurodivergent children, as with neurotypical children, were able to weigh the risks and benefits of XR in their lives. In Jin

et al. (2024), three key ethical themes were raised specifically by neurotypical children (alongside their parents): the erosion of physical community bonds and social connections, long-term negative effects on children’s health and development, and risks to children’s safety and privacy in VR environments. In this study, ethical concerns of XR raised by neurodivergent children included but also expanded upon these themes. For instance, neurodivergent children articulated personal difficulties with addictive patterns of technology use, time blindness while engaging in immersive digital play, VR induced seizures, and heightened emotional intensity from fearful or anxiety-inducing VR experiences, which may reflect greater challenges with epilepsy, executive functioning, and mental health among those who are autistic and/or have ADHD (Astle et al., 2022).

In addition, child participants in Jin et al.’s (2024) study recognized the potential of XR to beneficially support social connectedness, educational opportunity, and user agency. In our work, possible benefits of XR brought up by neurodivergent children spanned related topics as well as other perceived beneficial dimensions. Children in our study, for example, found VR schooling appealing not only on the basis of potentially more engaging learning, but for a reason having nothing to do with the classroom itself—eliminating challenging morning transitions to school. Transitions between activities can be significant sources of tension between neurodivergent children and their parents, as well as stressful for the neurodivergent child (Stoner et al., 2007), so it is understandable that this could be part of the appeal of XR.

5.2. Design, ethical, and research implications for neurodivergent children’s XR use

Neurodivergent children’s reflections of their past XR experiences, their responses to potential applications of XR in their daily lives, and their conversations about the ethical choices to be made about XR futures have direct implications for the design of XR, ethical principles to uphold, and future CCI research inclusive of autistic children and/or those with ADHD.

5.2.1. Design

Studies of neurodivergent children’s digital and physical play preferences overlaps with our findings in several respects (Alper, 2023; Pavlopoulou et al., 2022), and together point to implications for more ethical XR design. O’Keeffe and McNally, 2025 found that autistic children value play that is enjoyable and pleasurable (when fun and offering flow/immersive escape), socially connected (when supporting friendships in an adaptive manner) with solitary play sometimes preferred, and meaningful (when providing appropriate sensory/physical stimulation, creative outlets, and opportunity to explore intense interests). Boyd (2019) has also highlighted the importance of sensory-inclusive design in neurodivergent children’s virtual play spaces (i.e., assistive technologies) as well as virtual play spaces that neurodivergent children may enjoy (i.e., mainstream technologies).

There are several XR design opportunities and approaches highlighted by the needs and concerns of neurodivergent children in our study (Table 5). Perhaps most importantly, children emphasized that design should be conducted in an inclusive way with autistic people and those with ADHD. Designers should include neurodivergent populations in their design and user testing through accessible and participatory research processes (Spiel et al., 2017) to better understand how these populations experience XR and design accordingly. Specifically related to design, children in this study talked about issues related to sensory processing. Designers should consider differential effects of the overstimulating potential of VR and its impacts on children by age and ability (for instance, C6 discussing how too many game choices at VR setup would be inappropriate for younger kids.) Designing smoother transitions onto and off of VR headsets could lessen sensory dysregulation, such as scaffolding a VR experience so that it gradually adds more immersion or stimulus (Knibbe et al., 2018).

Table 5
XR design recommendations.

Recommended Features	Related Access Concerns	Examples from Prior Work and Commercial Products
Minimizing game choices at XR setup	Sensory overstimulation	<i>Bob’s Fish Shop</i> ; Boyd et al., 2018; Simmons et al., 2023
Smoother sensory transitions onto/off XR	Sensory overstimulation	Floreo VR platform; Boyd et al., 2018; Hutson & McGinley, 2023
On-screen timers in VR headsets	Limited temporal awareness (i.e., “time blindness”)	Mullen and Davidenko (2021)
“Passthrough” or mixed reality mode	Missed spatial and social cues	MiRA, a projection-based museum system; Saviano et al., 2024
Social co-use via screen cast of solo VR game play	Inflexible social configurations	<i>Keep Talking and Nobody Explodes</i> ; Clevr; Thompson et al., 2018

As several children were concerned about limited spatial, social, and temporal awareness in XR, designers could respond by allowing for on-screen timers that help them regulate their time, as well as ways to enable users to more easily pick up on spatial and social cues, such as allowing applications to run in “passthrough” or mixed reality mode where the physical world is visible. Neurodivergent children in our study desired a variety of social configurations with VR, including solo play, co-play, and vicarious play with both co-located and remote social partners. Designers should consider varied modes for applications that limit or expand social interaction, and consider the potential for children’s co-use involving watching a screencast of another’s VR game play (e.g., TV, mobile device screen). These configurations open up the potential for XR to be used more easily by multiple people at a time, and also raise ethical questions regarding who counts as an XR “user.”

5.2.2. Ethics

XR remains a contentious ethical issue for disabled populations, with some HCI researchers contending that VR is inherently discriminatory towards disabled users because it presumes interaction patterns and physical movements that privilege the non-disabled (Gerling & Spiel, 2021). The ethical issues identified by neurodivergent children in our study echo concerns highlighted in prior XR ethics research with neurodivergent adults (Creed et al., 2024), as well as non-XR based on work neurodivergent young people’s concerns about media risks (e.g., heightened rates of cyberbullying; Anderson & Phillips, 2019). Those issues included fears about AR/VR enabling discrimination and abuse, heightened risks for addictive patterns of immersive AR/VR use, a lack of protections and support for vulnerable users in shared virtual spaces, negative physical and mental impacts of the technology’s hyperrealism, and the potential for AR/VR to be a retreat from in-person socializing.

As noted above, neurodivergent child participants in our study also discussed the importance of including neurodivergent individuals in the design and development of XR, a priority that prior research has similarly evidenced among neurodivergent adults (Schmidt et al., 2023). Neurodivergent children also had ideas about who should make rules regarding XR for young people. They suggested that parents and children set boundaries together, while being skeptical of authority figures like politicians and teachers. They recognized needing help with regulating their use of XR but wanted some agency in the process, and saw their parents as offering that negotiation and personalization. Fully incorporating participant suggestions though, such as the benefits of escaping physical reality, also raises its own ethical issues. For example, XR schooling could lead to digitally segregating neurodivergent learners. Benefits and drawbacks of XR are entangled with respect to disability rights, design justice, and the social model of disability (Costanza-Chock, 2020), as the decision to use XR for accessibility purposes represents tensions between how much neurodivergent people

need to accommodate to a neurotypical society and vice versa. Extended reality technologies may be a temporary solution while designers negotiate how to build a more accessible society from which neurodivergent children do not feel a need to retreat.

5.2.3. Research

Our work has applications for future research directions in XR as well as methodological considerations for CCI research with neurodivergent children. The ethics of AR and MR should further be explored with neurodivergent children, as the video scenarios in our study focused on VR exclusively. Children's prior experiences with digital platforms such as Roblox and Zoom (particularly during the COVID-19 lockdown) shaped their attitudes towards XR in our work, and XR research with neurodivergent children should account for their views on the ethics of these related technologies. Future work might thread apart differences between those with dual diagnoses of autism and ADHD and those with single diagnoses with respect to experiences with emerging technologies, specific risks and benefits, and perspectives on ethical implications. Research should also further investigate age-related differences across the pre- and early adolescent years of 8–13. In addition, follow up studies should incorporate the perspectives of stakeholders who provide neurodivergent children with social support and manage their technology use (e.g., parents, educators, clinicians) (Schmidt et al., 2023).

Methodologically, researchers using fictional scenarios with neurodivergent children may need to demonstrate greater flexibility in providing alternative versions (e.g., simplified versions for those with intellectual disabilities), as autistic children and/or those with ADHD can get caught up in details that unduly influence their attitudes. For instance, the Family Utopian scenario was reportedly less appealing to some neurodivergent children because it involved playing Monopoly (e.g., C6 did not like that game, C1 did not enjoy competitive board games). Neurodivergent children's responses may have been hindered by the general use of utopian/dystopian scenarios, given their inherent binaries and limited potential for free association (Harrington & Dillahun, 2021). Considering the fact that many neurodivergent youth have an affinity for science fiction fandoms (Fein, 2015), researchers might consider drawing upon existing media texts that illustrate possible XR futures as an entry point for neurodivergent children and adolescents to discuss ethical implications.

In addition, conversational AI platform ChatGPT was offered by one neurodivergent child participant as a possible tool for developing future XR scenarios (though a tool that paradoxically begets its own ethical complexities). Studies suggest that ChatGPT is considered to be a novel form of assistive technology by autistic adults (Choi et al., 2024). Its everyday use among neurodivergent children has not been studied in depth, though some work suggests that this population may find chatbots and conversational agents to be interesting and entertaining interlocutors (Cha et al., 2021), with concurrent risks for developing addictive, anti-social, and risky patterns of use, particularly if incorporated into XR technology. C14 was so interested in thinking through school discipline in a VR context that they noted, "I'm probably gonna ask ChatGPT about this, just to see what would happen." Later in the interview, when narrating a scenario in which parents of a child accused of misconduct in VR class meet with school administrators, C14 envisioned ChatGPT extending their musings: "I bet the VR camera has like a video, so you can just see what happened during the day. [...] I'm gonna ask Chat GPT to make a story about this. Because this is actually interesting." Though autistic children are commonly assumed to lack "theory of mind" and have difficulty consider the viewpoints of others (Gernsbacher & Yergeau, 2019), C14 illustrates not only that some neurodivergent children are adept at perspective taking (perhaps even more so than some neurotypical children), but also that AI might enable them to consider several factors and positions simultaneously.

6. Conclusion

XR technologies have spurred significant speculation regarding their promises and perils, especially for children. In some respects, XR magnifies ethical questions raised by existing technologies (e.g., networked video games), and yet in other ways, they present new dimensions (Anderson & Rainie, 2022). XR presents both unprecedented opportunities and complex challenges for neurodivergent children, including but not limited to uses within the contexts of education, healthcare, and leisure. As the field of XR is rapidly developing, it is difficult to predict future impacts and possible (mis)uses. It is important to have on-going feedback on ethical concerns about XR technologies from a diverse group of stakeholders (including parents, educators, neurodivergent children, and child advocates), informed by existing literature from the field of HCI, CCI, and other adjacent fields, which this study has accomplished. We found that neurodivergent kids can engage in ethical reasoning around the future of immersive technologies. The issues they raise may be similar in some respect to neurotypical children (e.g., eye strain) and have similar limitations (e.g., younger ages struggle to see ethical gray areas), but they also bring up unique ways of discussing ethics (e.g., enacting imagined conversations and elaborate scenarios), specific dimensions (e.g., inclusion of autistic voices in ethical technology decision-making), and remarkable self-awareness (e.g., addictive potential of XR).

7. Selection and participation

We received IRB permission from [anonymized university] to conduct research on XR ethics with neurodivergent children and their parents. A total of 21 children ages 8–13 and a parent of each child took part in the study. Parent recruitment was digitally facilitated through social media, blog posts, emails to parent disability advocacy groups, and flyer distribution to local clinical centers serving autistic children. Parents provided digitally signed written consent. Child participants provided assent at the start of the remote interview verbally (e.g., "Yes"; "OK") and/or physically (i.e., thumbs up sign). Regarding data sharing, adult participants were told that only the researchers on this study would see information about them and their child and that records of this study will be kept private. They were told that the Zoom interviews would be anonymized (e.g., any name mentions removed) and transcribed and that the research team would not share these records publicly. During the assent process, child participants were told that we would not put their name on any information that they shared, but to please only share information that they would not mind the research team members knowing. Additional ethical considerations for conducting research with neurodivergent child populations were considered, including enabling live closed captioning on the Zoom call and VR video scenarios if requested and including visual representations alongside on-screen text to support comprehension.

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CRedit authorship contribution statement

Meryl Alper: Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Eunju Pak:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Eileen McGivney:** Writing – review & editing, Methodology, Investigation. **Veronica Rubinsztain:** Writing – review & editing, Investigation, Formal analysis, Data curation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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