Is Your Family Ready for VR? Ethical Concerns and Considerations in Children's VR Usage

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ABSTRACT

Virtual Reality (VR) has emerged as a transformative technology to revolutionize education, socialization, and entertainment. However, alongside its promising applications, concerns about potential risks, particularly for young children, have surfaced. We conducted a survey and interview study with 55 parents and 67 children aged 7-13, to identify ethical concerns and design considerations for VR usage in youth populations. This study contributes to the HCI community by providing empirical insights into the ethical concerns surrounding children's VR usage, as viewed from both children's and their parents' perspectives. These insights stem directly from their perceptions of the risks, benefits, and considerations associated with VR across various usage scenarios. Additionally, our research offers valuable design and research implications for the development of responsible VR practices that balance the advantages and potential risks for children and their families.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; **Virtual reality**.

KEYWORDS

Virtual Reality, Children, Ethic, Ethical Concerns, Family, Social VR

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1 INTRODUCTION

Virtual Reality (VR) has emerged as a powerful technology that has the potential to revolutionize the way children learn, play, and communicate. With VR, children can explore immersive virtual environments and interact with digital objects in various contexts (e.g., education [4, 68, 69, 77], socialization [4], entertainment [36], health [18, 57]). For instance, researchers have developed educational VR games that allow children to learn about science [43], math [49], and other subjects [67] in a fun and interactive way. Apart from education, VR has also been used for entertainment purposes. Children can use VR devices to explore different virtual environments, including amusement parks, museums, and other places of interest [34]. Moreover, VR has been used in therapy for children with various conditions, including pain management [75], eating disorders and obesity[33], anxiety [32, 83], ADHD [64], and autism [14].

Despite VR's exciting possibilities, there are concerns about its potential risks and drawbacks, particularly for young children. One literature review (2010-2020) [45] outlines emerging ethical issues and worries of parents, educators and experts, including the impact on children's cognitive development and physical health, cybersickness and visual disturbance. The immersive nature of VR might also raise ethical concerns about issues such as privacy, safety, and content appropriateness [48]. Most of the work identifies these concerns from the perspectives of adults, ignoring children's viewpoints. In our work, we recruited 55 parents [1] and 67 children between the ages of 7-13, aiming to investigate the ethical concerns and considerations from a more comprehensive, integrated perspective. Specifically, this work aims to address two pivotal research questions:

- (RQ1) What are parents' and children's primary ethical concerns concerning VR use by children ages 7-13?
- (RQ2) What specific considerations must be taken into account for youth populations when designing and implementing VR in different contexts?

[1] In this work, the term "parents" is used in a broader sense. While it primarily refers to parents, it also includes other guardians and adult family members (e.g., grandparents, siblings).

Our investigation identified primary ethical concerns, including the erosion of physical community bonds and social connections, long-term negative effects on children's health and development, risks to children's safety and privacy, and disparities in equity and inclusion. Furthermore, we highlighted key considerations for designing and implementing VR for youth, emphasizing the importance of promoting open communication to recognize the benefits and risks and the critical role of parental supervision and control. Based on these findings, we reflect on the tension of stakeholders and present implications that aim to contribute to responsible VR design practices.

This study contributes to the field by providing an empirical understanding of ethical concerns in children's VR use from both children's and their parents' perspectives, directly derived from their perceived risks, benefits, and considerations associated with VR in a range of usage scenarios. We gathered data from a diverse group of 122 participants, ensuring a wide representation across different ethnicities, technologies, and socio-economic backgrounds. Additionally, this study offers design and research implications for developing responsible VR practices that balance benefits with potential risks for children and families.

2 RELATED WORK

2.1 Children and Immersive Virtual Reality

VR refers to a synthetic world that users can completely immerse themselves in without seeing the real world [24]. The immersive nature of VR nowadays is often realized by using a head-mounted display, connected to or embedded with a computer that allows users to physically move or use controllers to navigate within a 3D virtual environment. With the immersive experience provided by VR technologies, researchers have investigated the application of VR in medical context for children, such as facilitating pain management [74], or being used as a distraction during medical procedures (e.g., [31, 50]). The engaging experience provided by VR can also help motivate children's participation in various health-related interventions (e.g., [11, 35, 56, 78]). Lin et al. developed a VR game aimed to promote emotional health for adolescents between 13-17 years old [50], where the immersive nature associated with VR game demonstrated effectiveness in enhancing their emotional well-being based on their preliminary results.

The recent advances in technology have expanded access to VR at a lower cost, providing opportunities for children's VR usage beyond medical context. In the educational and learning context, smartphones and low-cost viewers can provide K-12 students with cost-effective ways to experience 360-degree images and videos, which allow them to be immersed in other locations, places, and times [34]. Still, these low-cost VR technologies are effective in arousing children's curiosity and leading to a more engaging learning experience with the topic, which demonstrates potential in VR for children in low-resource environments [84]. Researchers have also investigated using VR to help children develop various skills and learn specific concepts (e.g., programming [42], art [25] and math [49]). For example, an immersive VR environment can be used as a shared educational space for children's collaborative learning experience [53].

Although the majority of prior literature has focused on the contexts of medical and educational usage when investigating VR for children, a few recent research has set out to understand children's usage in more day-to-day settings, such as social interactions and connections (e.g., [8, 28, 85]). As commercial social VR applications (e.g., *VRChat*, *AltSpace*) become more available to young users, Maloney et al. [54] conducted an interview study to understand people's experience and perceptions on interacting with young users in these apps. They found that social VR applications have attracted a large number of young people, but the interactions with children can be complicated on these social platforms due to various concerns such as privacy and online harassment. However, more knowledge is still needed about VR usage and its potential risks in various contexts that are important aspects of children's daily lives. With the growing VR content and more available commercial VR headsets, our work wanted to gain a holistic view of potential risks and considerations associated with children's VR usage in a range of settings, through an inclusive sampling that encompasses a wide spectrum of demographics.

2.2 Concerns around General VR Usage

Despite the many benefits associated with VR usage, concerns exist regarding VR usage. The head-mount display and 3D viewing often raise concerns about VR's potential impact on users' health, such as cognitive and physical abilities, or the side effect of motion sickness [47, 63]. The rapidly growing VR content and usage also raises concerns about users' privacy and other's toxic behaviors online [17, 29]. Through an interview study, Blackwell et al. [17] found that norm formation can be especially difficult in social VR, which brings more challenges when mitigating harassment. People are also often more cautious with VR usage in some specific contexts, such as education and healthcare [45]. For example, in educational settings, adopting VR in the classroom can imply extra burden for instructors in course design, effort in managing technology at the same time as managing the classroom, as well as potential financial considerations when investing the hardware [41].

Concerns and questions are also raised specifically around children's VR usage, since children are often considered a user group with more vulnerability. One of the main concerns is about its potential health and safety effects, along with the appropriateness of VR content for younger users. Many VR hardware manufacturers suggest a minimum age for VR usage, typically setting the age threshold at 10 (e.g., Meta Quest 3 [1]), 12 (e.g., Sony PlayStation VR [72]), or 13 years (e.g., Samsung Gear VR [72]) to create accounts or use their devices. A few companies also provide parent-managed accounts for children who are 10-12 years old [2]. One major health concern raised is the potential damage to the immature visuomotor system [71, 80], principally adverse effects on accommodation, vergence, and stereoscopic vision. This is generally expected based on side effects experienced in adults [62, 71]. However, the prevalence of discomfort and aftereffects may be less for children than what has been reported for adults. One scientific research [81] investigated 50 children aged 4-10 years who tolerated fully immersive 3D virtual reality game in a before-and-after study. Their results showed that VR play (with 30-min VR exposure) did not induce significant post-VR postural instability and motion sickness among

their participants. Similarly, works investigating the effect of 3D video gaming and immersive VR experience found minor or negligible health-related effects on children under 14 years old. Pölönen et al. found children's symptoms of eyestrain or motion sickness were minor and less than those reported in adults subjected to the same viewing experience, when investigating the after play effect of 3D video game on 8-14 years old children [65]. Similarly, Bendiksen et al. found only minor negative effects on children under 12 years old after using VR headset (i.e., mild dizziness and nausea with no loss of balance reported) [15].

Our work investigated the concerns on children's VR usage from users'—children's and their parents'—perspectives, understanding their perceived risks and considerations associated with VR usage. Since most of the prior work focused on studying the health-related effects associated with children's VR usage through lab or experiment studies, there is a lack of understanding about direct users' perspectives, especially ethical considerations, that can help guide best practices for designers and researchers to develop appropriate VR technology and content for children.

2.3 Ethics around Emerging Technology for Children

Emerging technology, which refers to the new and rapidly evolving technological innovations that are still in the developmental phase and may not yet be adopted widely, often have great potential to significantly impact society and the economy. Emerging technologies such as AI, robots, conversational agents, and VR especially are thought to hold promises for children's usage. For example, tutoring robots can help provide children with personalized content and even have the potential to engage children socially while learning [73]. Investigating the potential ethical considerations around children's use of emerging technologies remains an important topic for technology researchers, since children are a special group of users who often have unique needs and requirements and can be easily influenced by their technology usage [38, 44]. Because of their vulnerability, inappropriate technology design and experience can have more detrimental effects on children's development as well as their interactions with their family, peers, and community, compared to potential impacts on adults [59].

However, ethical assessment of emerging technologies can be challenging because of their unpredictable usage and the rapid evolution of their applications [22, 38]. Prior work in the area has suggested several specific methods to address these challenges, including: examining the inherent properties of technologies for potential ethical issues provided by ethical tools or checklists [23, 26]; developing scenarios for anticipated future uses to facilitate risk-benefit analyses [19]; and using participatory methods to gather stakeholder insights on ethical matters [10]. Besides, ethical assessment of emerging technologies for children often needs to include other relevant stakeholders, such as parents, educators, and health providers, which can bring additional challenges. To help researchers better design trustworthy conversational agents for children, Brummelen et al. conducted a workshop with both children and parents, which helped researchers understand potential disparities between generations' perspectives for future design [82]. Although HCI and IDC researchers have discussed various ethical concerns about children's VR usage in different scenarios and contexts [45], there is a lack of empirical understanding about ethical considerations regarding VR for children that incorporating both parents' and children's perspectives, as well as how these considerations might vary or remain between different usage contexts. Our work aimed to address this gap and form guidance for researchers and designers to better include these ethical considerations when designing and researching VR for children.

3 METHODS

We conducted a study with 122 participants (56 groups) to investigate the concerns and considerations for children's use of VR technologies. We describe the setting and participants, the procedure followed, artifacts and measures used, analyses employed, and the limitations of our methods.

3.1 Setting and Participants

We received IRB permission to work with the Driven to Discover research facility at the Minnesota State Fair. This research facility, known as a "lab-in-the-wild," offers an opportunity to engage with a diverse group of participants, especially families. Participant recruitment for this study was conducted as families with children passed by the Driven to Discover Research Facility on the fairgrounds. Research procedures would also be conducted in this same building. Our research settings include desks and swivel chairs, headsets, recorders, and tablets for filling out the consent, demographics and survey (as shown in Figure 1).

Figure 1: Participants (colored in white) were playing with VR in our study. Two researchers (colored in blue) were monitoring the process.

We recruited a total of 122 participants, including 67 children and 55 parents, who were enlisted from 52 families, and subsequently organized into 56 groups. Among these 56 groups, 45 comprised pairs (consisting of one parent and one child), nine formed trios (comprising one parent and two children), and one group included one parent and three children. Additionally, one group consisted of a single child who completed the study, with the parent providing consent and demographic information. Among these groups, two pairs did not complete the study; therefore, only saved data was collected from participants.

The adult guardians, primarily parents, accounted for 79.1% (N = 53) of the total, while 5.97% were siblings (N = 4), 5.97% were other direct family members (N = 4), 4.47% were grandparents (N = 3), and 4.47% were other non-family members (N = 3). Their average age was 42.07 (SD = 8.94), consisting of 32 females and 23 males. In terms of ethnicity, 81.82% identified as White (N = 45), 7.27% as Latinx (N = 4), 5.45% as Black (N = 3), with 18.18% identifying as others (N = 3). Approximately 36.36% did not possess a college or advanced degree (N = 20), while 18.18% reported an annual family income of less than $75,000 (N = 10). 42.82% had previous experience with VR technology (N = 23).

The children, with an average age of 10.46 (SD = 1.9), comprised 38 females and 29 males. We were originally targeting age range 7 to 13 years; however, certain exceptions were made to accommodate children slightly older or younger. These exceptions were made, for instance, if a child had a sibling participating in the study and expressed a strong desire to join, provided they were in close proximity to the targeted age range. As a result, we included one six-year-old and one 15-year-old participant. Of these children, 76.12% were identified as White (N = 51), 10.45% as Black (N = 7), 7.46% as Latinx (N = 5) and others were classified as belonging to other ethnicities (N = 4). Interestingly, 44.78% of the children reported prior experience with VR (N = 30), a percentage higher than that observed among adults.

During the study (see Section 3.2), participants chose two out of three preferred areas for scenario viewing. Guardians primarily selected the education area (78%, N = 43), with a smaller percentage choosing family (65%, N = 36) and healthcare (55%, N = 30). Among children, 88% chose education (N = 60), 79% selected the family area (N = 54), and 31% chose healthcare (N = 21). All participants would receive a backpack or a stuffy toy as a token of appreciation for their involvement.

3.2 Procedure

The study lasts about 20 minutes in total (see Figure 2). Researchers introduced the study to the guardians, allowing them to complete consent forms for themselves and their children. Demographic questionnaires were filled out on tablets by guardians as well. Simultaneously, another researcher verbally explained the assent form to the child to get their verbal consent, addressing questions if any. When two or three children participated with the same guardian, they constituted the same group. In such cases, each child accompanied by one researcher, completed the consent process individually.

To introduce participants to VR technology, researchers then guided children and their guardians to the VR activity space within a 360-degree video co-watching application (see section 3.3.1), and helped them adjust the headsets and controllers. Here, the child and their guardian could navigate and explore different rooms within a shared space station. As they journeyed through the virtual environment, they were encouraged to describe what they observed and pose questions to each other. This step took about 5 minutes.

Then, participants were tasked with selecting one out of three areas (education, healthcare and family) of interest. They would view two scenario videos within their chosen area in a random order, each approximately lasted one minute. After each video, participants responded to three Likert scale questions aimed at exploring the perceived positives and negatives of VR technology as outlined in the scenarios. Next, they would select another area and follow similar steps to watch the scenarios and fill out the survey. This step took about 6 minutes.

Finally, participants underwent separate but parallel semi-structured interviews for the following 7 minutes, with visibility to one another. These interviews were audio-recorded for subsequent analysis.

3.3 Artifacts and Instrumentation

3.3.1 VR Exploration System. We developed a VR exploration system to give participants, especially for those who had no prior VR experience, an opportunity to try this technology. This system comprises five 360-degree video clips, each showcasing different rooms and astronauts' activities within the space station. Each clip has a duration of approximate 1.5 minutes and was sourced from the European Space Agency's International Space Station tour [2]. In the VR environment, participants are represented by a neutral, robot-like avatar, separated by colors. They can utilize the trigger button on their controller to select the room they wish to enter, aligning with the door shown in the video content. Notably, using this button allows them to bring their partner(s) into the same room, ensuring that the entire group experiences the synchronized video context.

We conducted a pilot test with eight college students to ensure that the system is user-friendly and can be operated without the need for training. Based on their feedback, we adjusted the button placements and designs, and simplified controller operations by allowing only one button to switch between rooms.

3.3.2 Scenarios and Survey. We adopted an anticipatory approach, as commonly used to examine the ethical aspects of emerging technologies [22], designing scenarios that describe potential future integrations of VR technologies into three areas: education, healthcare, and family. We chose these three areas due to their profound impact on children's lives.

As technological changes are often conceived of as variables with at least two potential outcomes [19], we developed two narrative scenarios for each area, showcasing both potential positive impact (utopian) and negative impact (dystopian). These scenarios act as intuitive stimuli and provide a foundation for thinking about and discussing the ethical issues encountered during the study. It is important to note that we did not explicitly label them as utopian or dystopian to allow participants to form their own interpretations and judgments about the scenario. A summary of these scenarios is listed below. Figure 4 shows an example of the depicted scenario; full scenarios can be found in Appendix A.

- Education Utopia (EU): VR experiences augmenting an after-school STEM program.
- Education Dystopia (ED): VR shifts to education entirely within a virtual school setting.
- Healthcare Utopia (HU): Use of VR for distraction during children's medical MRI procedures.
- Healthcare Dystopia (HD): Children using VR to cope with pain and avoid physical exertion in post-medical procedures.

[2] https://www.esa.int/ESA_Multimedia/Sets/Space_Station_360_ISS_tour

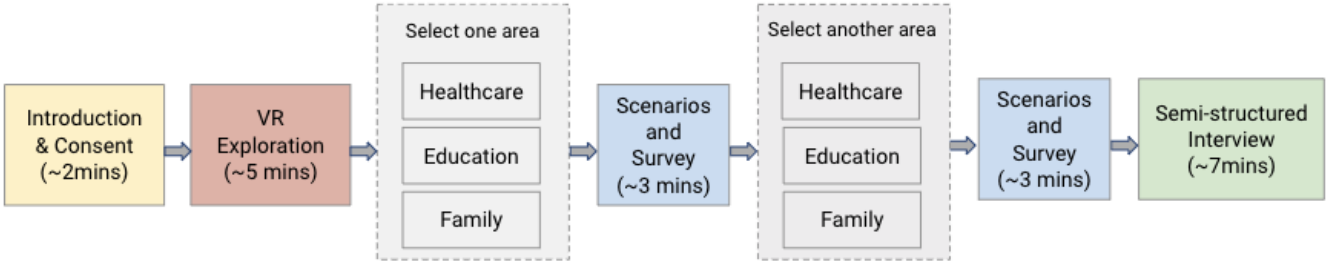

Figure 2: Overview of the study procedure.

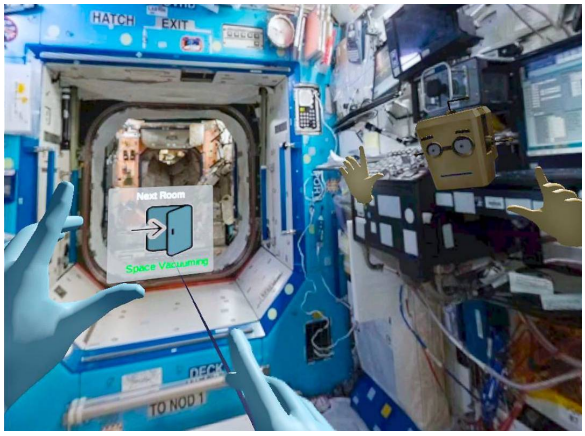

Figure 3: VR exploration system.

- Family Utopia (FU): Family engaging together in VR gameplay.
- Family Dystopia (FD): Family members individually immersed in separate VR experiences while together physically.

To gain a macro-picture of parents' and children' attitudes towards these scenarios, and to collect quantitative data that triangulates with the interview data to answer RQs, we employed Likert scales to measure attitudes for each scenario (Figure 5). The Likert-type response format for adults involved indicates whether they strongly agree, agree, neutral, disagree, or strongly disagree with each item. Items were randomized within the survey. To design the Likert scale for children, we adhered to the recommended approach outlined in Royeen's work [70] and adapted the adult version to a 3-item response format: *No*, *A little*, and *A lot*. These responses were presented in three corresponding blocks, each measuring 2*2 inches, 2*3 inches, and 2*4 inches (Figure 6).

In order to ensure the clarity and readability of the questions and statements for participants, especially for children, we conducted a pilot study involving six adults and three children recruited through personal connections who voluntarily participated. With the first three adult participants, we guided participants through the entire process, collected their feedback, and identified any issues. Subsequently, we formulated and tested revised questions with the rest of the pilot participants to ensure that both parents and children could readily understand our inquiries.

3.3.3 Semi-structured interview. Interviews were conducted separately and individually for each participant. During the interview, the researcher would initiate the conversation by reminding the areas participants previously chose. They would be asked about their thoughts on the use of VR in the stories presented to them and what aspects of these stories stood out. For example, participants would be asked about benefits, potential issues or problems that VR might create for their children and families. Participants would be asked about who should be responsible for deciding which VR experiences are suitable for children, and the considerations that creators should keep in mind when designing VR for children and families. Finally, we concluded the interview by inviting participants to share any additional insights or thoughts about VR for families.

Children were asked similar content but conveyed using child-friendly phrasings, and the readability and clarity were tested in the same pilot study with the procedure mentioned before (section 3.3.2).

3.4 Data Analysis

In order to answer the two research questions, we analyzed the quantitative results from the survey, and qualitative results from the interviews and observation notes. For the quantitative data, we converted the Likert scale responses into a numerical format, where we assigned weights ranging from 1 to 5 for adults' Likert scale responses (e.g., *Strongly Disagree* to *Strongly Agree*). For children's Likert scale responses, we employed a similar approach, mapping *No* to 1, *Little* to 3, and *A lot* to 5, ensuring a consistent scale. The higher weight would indicate a more favorable attitude. Subsequently, we performed a descriptive analysis of the data, computing statistical measures such as mean, median, and standard deviation to discern central tendencies and variations within the dataset.

The qualitative component of our analysis involved a systematic process inspired by data-driven thematic analysis, drawing upon the principles of the Grounded Theory Method [60]. Initially, we transcribed the audio recordings of the interviews, converting them into textual data. Two of our authors, who were actively engaged in the interview process and trained with open-coding methods [13], conducted open coding of the transcripts and supplemented them with memos derived from researcher notes. Subsequently, three authors worked together to group and cluster the open codes, employing a constant comparison approach that manifested as an

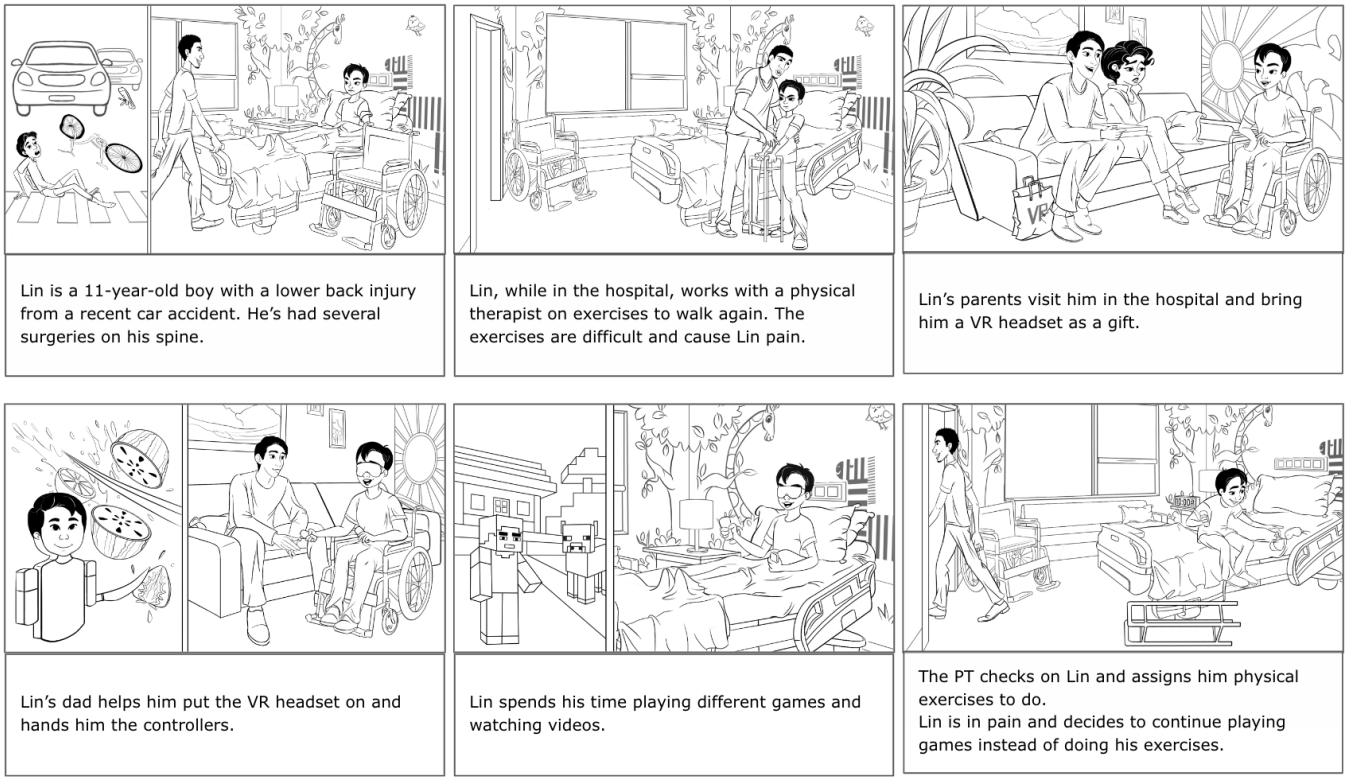

Figure 4: Scenario example in healthcare (shown as videos during the study). This dystopia scenario describes a child using VR to escape the pain post a medical procedure.

Figure 5: Items and Likert scales were used for adults. Items are displayed in a random order.

affinity map. The affinity map facilitated the arrangement of open codes with shared meanings into coherent clusters. The iterative refinement of these clusters ultimately yielded emergent themes. Once the iterative analysis process was completed, all authors collectively deliberated on the significance and novelty of the identified themes, which are subsequently presented in the results.

3.5 Limitations and Trade-offs

This research employed an anticipatory approach [23] of projecting future scenarios for parents and children. We chose this approach because these scenarios enable participants to envisage future developments in a concrete and engaging way, particularly crucial for children and adult participants from various socio-economic backgrounds. However, this approach may overlook the complexities of moral controversies and conflicts of VR usage for children beyond selected scenarios and areas. Additionally, there is an underlying assumption that ethic concerns remain static over time. This perspective aligns with the public's general expectation that technological advancements will support existing goals and values. The potential for technological change to dynamically alter moral beliefs is not fully acknowledged, leading to a possible oversight

Figure 6: Items and Likert scales were used for children. Items are displayed in a random order and are shown one at a time (on a single page).

in understanding the evolving relationship between technology and societal values [19]. Future research might explore alternative approaches to examining technology ethics, such as ethical Technology Assessment [61]. This method emphasizes the importance of ongoing dialogue between all relevant stakeholders and designers throughout the design process.

In addition, the study's relatively brief duration and participants engaging with a single VR application may have restricted the depth of insights we could gather. Longer interactions and more diverse VR experiences could yield more nuanced data and give participants greater time and experiences to generate ideas. While our study, with a sample size of 122 participants, represents one of the largest investigations into VR usage among children to date, practical constraints imposed a limit on the duration of the task. In our study, each pair dedicated 20 minutes to participation, leaving only 2 minutes for consent, 5 minutes for VR exploration, 6 minutes for viewing and completing the survey, and 7 minutes for the interview debrief. Due to time constraints, we had to simplify the VR system's operation to expedite the introductory phase. Collecting more extensive data would be feasible if participants were willing to devote additional time, allowing for more in-depth interviews. Furthermore, this study was conducted at a fairground which introduced background noise and distractions. This may affect participants' focus and responses during the VR experience and interviews, potentially reducing the ecological validity of the study. We encourage researchers to replicate aspects of this work with extended VR experiences, interview durations, and distraction-free environments, which will provide more detailed insights and inform the design of future studies.

4 RESULTS

Our results were derived from both quantitative (Figure 7) and qualitative analysis to present a picture of ethical concerns and considerations for children using VR. We first give an overview of our quantitative results, then divide findings into two sections: (1) primary ethical concerns of parents and children concerning the use of VR by children (RQ1) and (2) key considerations for designing and implementing VR for youth populations in various contexts (RQ2).

4.1 Overview of Post-Scenarios Survey Results

We utilized scenarios and surveys to gather insights into how parents and children perceive the use of VR in different settings, using this information to triangulate the qualitative data we present later. Below is a summary of the survey results:

As expected, participants had generally positive attitudes to all utopian scenarios, seeing higher approval and fewer concerns about using VR from parents and children. Participants maintained a strong belief in the positive outcomes of VR in these scenarios across three areas. Notably, VR use in healthcare received the most approval (P: M = 4.2, SD = 1.19; C: M = 4.43, SD = 0.93), with minimal concern about negative effects (P: M = 1.87, SD = 0.9; C: M = 2.05, SD = 1.2). Both groups expressed a strong belief in VR's potential in the healthcare area (P: M = 4.3, SD = 0.95; C: M = 4.52, SD = 0.87).

Attitudes towards dystopian scenarios varied across different areas. In the context of the dystopian scenario in education (ED), both parents and children showed a tendency towards neutrality (P: M = 3.1, SD = 1.19; C: M = 3.07, SD = 1.62), although with a slight positive lean in their approval of using VR to replace in-person schooling. Parents expressed significant concern in this scenario (M = 3.4, SD = 1.06), while children were less concerned (M = 2.8, SD = 1.27). Despite the caution in this scenario, there was still a prevailing positive belief among participants that VR could lead to beneficial outcomes (P: M = 3.26, SD = 1.15; C: M = 3.58, SD = 1.29).

In the healthcare dystopian scenario (HD), participants were still inclined to approve the use of VR (P: M = 3.37, SD = 1.25; C: M = 3.38, SD = 1.5), yet they expressed concerns about potential negative effects (P: M = 3.23, SD = 1.22; C: M = 3.86, SD = 1.2). Nevertheless, there was a tendency to hold a generally positive view of its potential benefits in this scenario for both parents and children (P: M = 3.23, SD = 1.25; C: M = 3.29, SD = 1.31).

In the family dystopian scenario (FD), parents were less likely to permit VR use by children (M = 2.69, SD = 1.06) and exhibited considerable concerns (M = 3.67, SD = 0.96), while children were still willing to engage with VR (M = 3.19, SD = 1.44) despite that it might create problems in children's lives (M = 3.19, SD = 1.44). Both groups suggested a belief that it would introduce negative effects on children (P: M = 2.69, SD = 1.06; C: M = 2.85, SD = 1.11).

Area		Education				Healthcare				Family			
Scenario		Utopia: VR experiences augmenting learning		Dystopia: VR experience replaces in-person learning		Utopia: Help child patients during medical procedures		Dystopia: children use VR to escape the pain post a medical procedure		Utopia: Joint Family VR Engagement		Dystopia: Family Separate VR Engagement	
Statement or questions / Roles (P: parents, C: children)		P	C	P	C	P	C	P	C	P	C	P	C
I would **approve** of the use of VR as shown in this story by my child. / Would you want to use VR as shown in this story?	Mdn	4	5	3	3	5	5	4	3	4	3	3	3
	M	4.1	3.98	3.1	3.07	4.2	4.43	3.37	3.38	4.06	3.38	2.69	3.19
	SD	1	1.14	1.19	1.62	1.19	0.93	1.25	1.5	0.98	1.43	1.06	1.44
I am **concerned** about the potential negative effects of VR as shown in this story. / Do you think using VR as shown in this story might create problems in children's lives?	Mdn	2	3	4	3	2	1	4	3	2	3	4	3
	M	2.32	2.42	3.4	2.8	1.87	2.05	3.23	3.86	2.39	2.46	3.67	3.19
	SD	0.93	1.23	1.06	1.27	0.9	1.2	1.22	1.2	0.93	1.38	0.96	1.44
I believe that using VR as shown in this story would bring **positive** outcomes to children and families. / Do you think using VR as shown in this story would help kids and the world in positive ways?	Mdn	4	3	4	3	4.5	5	4	3	4	3	2.5	3
	M	4.05	3.71	3.26	3.58	4.3	4.52	3.23	3.29	3.86	3.54	2.69	2.85
	SD	0.95	1.27	1.15	1.29	0.95	0.87	1.25	1.31	1.05	1.26	1.06	1.11

Figure 7: Survey results from parents and children for three areas: Education, Healthcare, and Family, across two scenario types: Utopia and Dystopia. The responses are color-coded to indicate the intensity of the attitude, with green representing positive attitudes and red representing negative attitudes (1 for strongly disagree (parents) or no (children) to 5 for strongly agree (parents) or a lot (children)).

4.2 Primary Ethical Concerns of Parents and Children towards VR Technologies (RQ1)

In this section, we detail four key themes describing the primary ethical concerns of children's VR use: erosion of physical community bonds, long-term health and development impacts, risks to safety and privacy, and equity and inclusion issues for VR as educational and developmental resources. Special emphasis is placed on those ethical concerns that are particularly important to children.

4.2.1 Erosion of Physical Community Bonds and Social Connections. As a medium for social engagement, VR has the potential to weaken children's ties to their immediate physical communities and change relationship dynamics. Such concerns were mainly reflected in the family and education-related scenarios where social connections are an important outcome. From the survey results of the FD scenario, both groups exhibited considerable concerns, indicating increased concerns within the family context. And this is the only scenario where most participants think it did not bring positive outcomes to children's lives. During the interview, our participants recalled FD scenario and noted that the convenience and allure of virtual interactions for children might diminish the value of in-person experiences and pose risks to "*prefer to stay in VR over spending time with friends and family*" (C1), leading to a form of **social isolation even in physically communal settings**. Participants observed a similar issue in the ED scenario of a fully virtual school. For example, one child commented in this scenario, "*I frowned when I saw that VR does not allow them to see their real classmates and teachers*" (C26). C26 also compared VR with his online learning experience.

> "I went through online school, that was a struggle. I think being there in real life would be a lot better than being able to just like log off and stuff, like to help pay attention and play with each other." (C26)

This feeling of social isolation is also caused by **difficulties conveying and cultivating emotional connections in VR**. Our participants pointed out that VR environments often fall short of accurately conveying the subtleties of human emotions compared with in-person interactions. Regular reliance on VR for social interaction poses a risk of stunting the development of deeper emotional and social bonds typically fostered through direct, real-life experiences. The nuances of "*non-verbal communication, empathy, and the richness of in-person emotional exchanges are difficult to replicate*" (P10) in virtual environments, thus hindering the depth and authenticity of social connections that can be formed.

The detachment from the physical world also raises another concern about the potential risk of children developing a **dependency on virtual environments** for entertainment, socialization, or escaping from reality. Compared with other digital devices, VR provides more immersive environments, "*having earbuds and screens separating them from their surroundings*" and making "*children totally zoned in*" (P28). The different and dramatic transition between the virtual and real world would cause more concern about being "*hard to bring back*" (P1).

VR's negative effects on the erosion of physical community bonds would be more severe for those children with special needs. P16, whose child has obsessive-compulsive disorder, said:

> "It would be like the one scenario (FD), he was at home and instead of going to dinner he was playing the game and that's what he would do. He would be too focused on the game and cannot stop himself from the virtual reality stuff as opposed to taking care of what needs to be done." (P16)

4.2.2 Long-Term Negative Effects on Children's Health and Development. Almost all participants in this study noted that they are worried about the immediate symptoms with VR usage, such as motion sickness or potential physical injury from tripping, running

into, or striking walls, furniture or other objects. Many health-related concerns about VR have been widely described in prior work (e.g., cybersickness and visual impairment [80]). However, most existing studies are short-term and conducted in laboratory settings. Compared with those immediate symptoms, there is a growing apprehension among participants about the potential long-term effects on children's health and development. This includes the broad spectrum of children's physical and mental health and the development of their cognitive abilities and social skills.

Many participants expressed **concerns about the long-term effects of VR exposure on children's physical health and development**. One notable issue is the potential negative impact on eye health, such as pinkeye, eye strain, and myopia, attributed to the proximity of the screen in VR devices, as one participant noted, "*the screen is much closer than other digital devices (P19)*." Additionally, the weight of current VR headsets suggests that they might adversely affect children's musculoskeletal development (e.g., causing neck damage discussed by C33). One parent, P13, also noted that utilizing controllers in VR fails to accurately replicate real-life movements, thus detrimental to developing children's motor skills, especially fine motor skills.

Moreover, the use of VR might lead to a reduction of physical activity and the acquisition of physical skills, as children may prefer VR activities over traditional play such as "*not spending enough time outside to do sports*" (C41). While VR technology does provide opportunities for encouraging physical movement, some participants indicated that VR usage leads to a predominantly stationary lifestyle and obesity, like P1 mentioned, "*it kind of reminds me of WALL-E* [3] *where they're in those chairs and never moved.*" Most importantly, engaging in physical activities through VR is markedly different from experiencing them in real life.

> "Sport (in VR) versus doing it in real life is very different. Actually, my daughter was trying to play a sport in real life, and she's like, wow, this is so much harder than the version of this (VR) when practicing breathing. So you think you're getting the experience, but it's still not the same as that real-life tactical thing." (P13)

In our survey results, these concerns were especially pronounced in the HD scenario, where VR is utilized by children as a way to evade physical therapy. Both parents and children had more concerns about VR's usage in this scenario. Participants' worries stem from the recognition that while VR offers engaging experiences, it should not replace activities fundamental to physical health in the formative years of childhood, especially for medical and rehabilitation purposes.

VR provides unique stimuli that differ from the real world. Participants noted their concerns about these differences leading to **unforeseen effects on cognitive ability and real-life skills development** from long-term VR usage, such as reducing children's attention spans, or negative consequences on how they process and learn information, understand and interact with the world around them. Both cognitive and social skills are essential for emotional regulation and resilience during children's development [79]. A lack of these skills can make it challenging for children to understand and manage their emotions and overcome challenges, leading to mental health issues (e.g., frustration, anger issues, or emotional distress). Artificially created VR environments struggle to fully replicate real-life situations, hence frequent use of VR might lead to an altered perception of real-world norms and expectations. Regular interaction with idealized VR environments may lead children to develop unrealistic expectations for the real world, particularly in VR scenarios lacking real-life consequences. This concern was highlighted in the education scenarios (EU).

> "Seeing, like field trips and museums, you learn how to stand in line, you learn how to wait your turn, you learn how to listen, and not be distracted. It's kind of like those people skills you learn. "(P17)
> "....that hands-on learning, that tactile is still so important for brain development and things like that where virtually they might get the experience but it's not the same as that kind of tactile experience of doing something." (P13)

As noted in the previous theme 4.2.1, VR might limit real-life social interactions and make it hard to convey emotions and concrete social cues. This further raises the concern that VR potentially **hinders the development of essential social and emotional skills**. Commenting on scenario FD, P56 said:

> "In the video, where the kid comes home and doesn't even say hi and goes and plays on their VR all day... it's less communication skills from person to person. I'm kind of like an introvert too, not an extrovert, so I don't have the knowledge or whatever to talk to other people. Social skills is what I can see causing the problem." (P56)

P21, a school teacher, shared similar concerns in responding to scenario ED:

> "I already see just from COVID, from kids distance learning for not even a year, most of them, like, the social interaction is so impaired. I wouldn't allow my kids to use it. Because I can imagine it's just gonna impair, the ability to actually look someone in the eye or use body language or just different stuff like that." (P21)

4.2.3 Risks to Children's Safety and Privacy in VR Environments. Children's safety and privacy in VR environments concerns various aspects, including exposure to inappropriate content, data privacy issues, online harassment, and cyberbullying. Many participants worried that children might **encounter content in VR that is not age-appropriate**, including material that involves violence, sexual content, or lack of moral integrity, which could pose a risk to their children's mental health and the development of their values. As a potential strategy, C13 emphasized the importance of VR developers identifying their target audience—adults, children, or a general audience—and ensuring that the game's content is appropriate for the intended age group.

Some parents also noted the **privacy vulnerability** that is inherent in the nature of VR when used by children, as VR systems often involve detailed tracking of user behavior, movements, and

[3] In 'WALL-E,' a Pixar animation, humans are depicted living in a future space colony where they lead sedentary lives, reliant on technology for all their needs.

preferences. Given children's limited understanding of data privacy and security, this raises significant ethical concerns about consent, data usage, and the long-term implications of having their early developmental stages monitored and potentially influenced by algorithmic content curation. P42 highlighted the difficulty children face in establishing authentication measures in VR to maintain their privacy and security.

> "My daughter always uses really basic passwords, like her name. Inputting the password by the VR controller also prevents her from setting up a more secure one." (P42)

Several participants expressed concerns that social VR platforms might expose children to **harassment and cyberbullying**. In the context of the ED scenario, participant P1 questioned the school's ability to safeguard against unauthorized individuals accessing a VR school environment.

> "Keep in mind safety controls, making sure that it's like a secure network so that strangers aren't coming on there or, you know, protecting kids from like their contacts with it. There are a lot of creepy people in the world. You go on Roblox and there are people there who are trying to distract children in negative ways. Hopefully, schools would have a way of preventing that." (P1)

P14 echoed these sentiments, emphasizing the need for heightened vigilance in protecting children with special needs from potential harassment and cyberbullying within VR educational settings.

4.2.4 Disparities in Equity and Inclusion to VR as Educational and Developmental Resources. Participants mentioned several equity issues related to their **socio-economic background**. On one hand, the high cost of VR technology can create a digital divide. Parents expressed their concerns that children in remote or underdeveloped areas/low-income families might have limited or no access to VR, leading to a gap in technological exposure and learning opportunities. On the other hand, using VR also requires related infrastructure, such as adequate physical space, internet connectivity, and potentially additional staff for teaching and technology support.

Even with sufficient access to a VR headset and the necessary infrastructure, ensuring that VR provides children with equivalent educational and developmental experiences still remains challenging. The current design of VR technology often **fails to account for children's inclusive needs**. As P16, a parent of a hard-of-hearing child, pointed out,

> "It's difficult for my child to have the same experiences as other children through VR because it's not designed with diverse needs in mind." (P16)

This lack of accessible design for varying abilities means children with disabilities might not fully benefit from VR. Additionally, the need for VR settings to be adjustable to different movement and immersion tolerances was highlighted by several parents. P7 elaborated on this concern, stating,

> "I know sometimes the weight of the headset could be too much for a kid. Some kids might be more prone to dizziness. Only for those can adjust the tolerance, things aren't spinning around as fast." (P7)

4.3 Key Considerations for Designing and Implementing VR for Youth Populations in Various Contexts (RQ2)

4.3.1 Promoting Open Communication to Recognize Benefits and Risks. Although we mentioned several ethical concerns above, most participants expressed a positive attitude towards VR, agreeing that when used properly, it can serve as a tool in complementary to benefit children. This echoed with prior works on the benefits of VR for children [7, 57]. Our survey results confirmed that, except for the FD scenario, both parents and children believe that using VR would help children positively. Our results clearly show that **VR has a dual impact on social connection, health and skills development, privacy and safety, and equit**y.

Regarding social connectedness, many participants recognized VR's ability to bridge distances, connecting children with family, friends, and peers in ways that mimic or even beyond face-to-face communication. This aspect of VR is essential in overcoming geographical barriers and fostering social interactions that might otherwise be challenging.

Similarly, for health and skills development, the participants concurred on VR's significant potential as an educational tool. This includes benefits such as "*enhanced visual learning and memory retention*" (P55), "*improved spatial learning*" (P40), and a diverse range of supplementary experiences (C1, C33), contributing to more engaging and effective learning experiences. Additionally, as shown in HU scenario, VR is recognized by our participants for its effectiveness in medical and therapeutic settings, serving as a distraction tool to alleviate pain and anxiety.

Regarding safety and privacy, participants acknowledged the protective aspects of VR, offering a secure environment during periods like quarantines and using anonymized digital avatars to safeguard personal identity. In addition, one child (C5) pointed out that the easy transition between real and virtual worlds created by VR can provide a means for moving away from bullying: "*it's easy to exit uncomfortable VR environments simply by removing the headset*", an option not available in real-life scenarios.

VR can also be a tool for addressing the equity issues in children's access to various resources and opportunities, especially for homeschoolers or children in isolated or rural areas with limited social and educational opportunities. For instance, VR can provide virtual access to distant or otherwise costly educational experiences, such as field trips, that would be inaccessible to some children due to geographical or financial constraints, as noted by P18. P33, a mother of a child with Asperger syndrome who was studying at homeschool, identified the inclusion as one benefit of VR:

> "just thinking from our mind, living in a rural area where he doesn't find a lot of kids like him, so a lot of times he connects with kids online. You know, through out-school classes or things like that. So it's really beneficial." (P33)

Many participants acknowledged the **challenge of understanding everything about VR but valued the opportunity to learn more for kids**. Based on the insights gathered from our interviews,

it becomes evident that while parents are considered the primary decision-makers regarding their children's VR usage, they hope to have guidance from "*people who are most familiar with it*" (P27) and ' *'who know how it impacts health and mind*" (C13) to help them navigate the uncertainties of VR's usage—providing parents with resources and information about VR's benefits and risks enables them to make informed decisions regarding their child's usage. These stakeholders include educators, VR industry professionals, child development experts, and healthcare professionals, and so on. Their involvement ensures that parents have access to essential information and expert opinions tailored to different contexts (especially for healthcare and education areas) of VR usage. For example, in the school context, teachers should be involved because they "*have the expertise to figure out which VR tool works best in the classroom, especially for the curriculum that they're trying to teach.*" (P51). And similarly in the healthcare area:

> "That depends on the settings (scenarios) that you're using it; if you're using it in a medical setting, I think that the parents and the doctors should discuss whether that makes sense for this child. Parents know their kids the best. Doctors can present possible positive uses."(P2)

Promoting bi-directional communication and active discussions among parents and various stakeholders are essential to ensure that designers prioritizes the most critical aspects that parents and children are attentive to (P12).

4.3.2 Supporting Parental Supervision and Control. When asked who should be the decision maker for VR's usage, both parents and children believed that parents should ultimately decide if their children are permitted to engage with VR, while also safeguarding them from its potential negative impacts. This responsibility, emerging from the uncertainties linked to VR usage, underlines key considerations in designing and implementing VR for youth populations of parental supervision and control. Some strategies for parental supervision in VR headsets have been implemented to keep children's health, safety, and privacy. For example, many participants noted the feature of setting screen time and schedule breaks to prevent VR overexposure to ensure that it doesn't interfere with physical activity, social interactions, and other important aspects of a child's development. Parents also mentioned the importance of controlling the content their children can access or purchase. Such parental tools have been integrated into some existing VR products. For example, in Meta Quest family center [2], parents can set up screen time and approve requests from their children if they want to download a new app. However, the current solution falls short of addressing parents' concerns completely, as it remains difficult for them to achieve comprehensive and flexible supervision and control.

First, current tools don't restrict the content they can access within an application and are **not comprehensive to protect children from potentially harmful or distressing experiences** in VR. There remains a concern that tech-savvy children might find ways to circumvent these restrictions or that they may encounter harmful content inadvertently through other means within the platform. For example, P33 expressed his worry about children potentially bypassing the restriction system if it is only based on age settings.

> "Video games have rating systems, movies have rating systems. Obviously that doesn't necessarily stop a child from playing those...They're smarter than we thought. "(P33)

Furthermore, these restrictions might not address the potential for indirect exposure to harmful content, such as through shared experiences or bystander interactions in multi-user VR spaces. For example, P23 noted that in the socialized VR environment, harassment and cyberbullying are hard to avoid through simple application restrictions. Although reporting systems can be integrated into such social VR applications, there is a lack of child-centric solutions to "*immediately safeguard themselves before the trauma occurred.*" (P51)

Existing ways are also **not flexible for parental monitoring and control**. Current VR technology includes a casting feature that allows streaming the VR headset's view to a mobile phone, TV, or monitor. However, parents face challenges in the way to monitor their children's VR usage because of its immersive nature. P8 compared his monitoring experiences with VR, noting the difficulty of peeking at the headset screen.

> "With a mobile phone, we can just glance over his shoulder, but with VR, we can't peek through the headset to see what he's up to... These virtual worlds are so big. It's hard to know everything that's in there." (P8)

Consistently monitoring the screen is also posing a challenge for parents. As P32 explains:

> "If they're at school, obviously they have to get a teacher to take care of them. But at home, it's harder to keep track. Because for me, I know I get busy, and I don't really pay attention to them sometimes." (P32)

Our participants expressed the need for various levels and tools for non-intrusive parental supervision and monitoring of their children's VR activities and interactions, allowing parents to view children's VR activities without needing to use the headset themselves. The noted tool features include 1) allowing parents to preview and approve VR applications for their children's use; 2) recording children's VR usage, enabling parents to review what their children have experienced retrospectively; and 3) an additional small screen on the headset or mobile phone for parents to quickly check on their children's current VR activity.

5 DISCUSSION

5.1 Reflection on Stakeholder Dynamics: Tensions among Stakeholders' Needs

Our findings in RQ2 (section 4.3) revealed a mixed impacts of VR, necessitating open communication that engages all stakeholders to investigate VR's longitudinal effects in different contexts. We also underscored parents' role in supervision and control to help mitigate VR's negative effects. In this section, we raise awareness of potential tensions between parents' and other stakeholders' needs and perceptions to (1) aid future designers and researchers in creating ethical and socially responsible products that balance diverse

requirements, and (2) highlight the areas that require regulatory attention to facilitate long-term adoption and acceptance of VR.

Parents vs. VR Industry. This tension arises from the VR industry's objectives which may differ from parents' needs or considerations. As shown in the results of RQ1 (section 4.2), parents tend to emphasize the practical, health and safety aspects in VR applications, as well as avoiding addiction or potential overuse risks. However, VR industry, driven by innovation and market expansion, may prioritize product profitability and user retention. This divergence in priorities and values can lead to conflicts in design, marketing, and regulation of VR products. For instance, concerns have been raised by our parent participants about potential data privacy breaches, such as the industry might exploit their children's data for commercial purposes.

Parents vs. Educational and Healthcare Entities. Our findings indicated VR's potential benefits and concerns in education and healthcare. Educational and healthcare entities might champion VR as an innovative tool for enhancing learning and rehabilitation, emphasizing its positive aspects, undermining its potential negative impacts. This active promotion may lead to a situation where parents feel pressured to consent their children for VR use when they still have reservations, particularly in schools where VR is integrated as part of the community's required educational framework.

Parents vs. Children. We found parents and children have different perspectives regarding VR usage and preference. Our survey results (see 4.1) indicate that children generally have a more positive attitude towards VR than their parents, even for dystopia scenarios. They perceived VR as an exciting and engaging platform for entertainment, social interaction, and learning, often preferring more engaging and interactive VR options. This preference can lead to disagreements with parents who may control and limit their VR's usage, which is also noted in prior research on children's digital device usage [46]. For instance, when observing the FD scenario, some children overlooked the aspect of family isolation due to VR use, instead, focused on the excitement of the VR content, such as the Minecraft presented in the scenario.

Given these tensions, future research should focus on developing strategies that mitigate competing interests and priorities between parents and other stakeholders, and support the roles they play in their children's VR technology usage. This requires sufficient information, informed consent, and open communication from the VR professionals and related institutions, that allow parents to make their own choices. One potential strategy can involve co-design practices that bring together industry professionals, domain experts, and families to investigate the properties of VR technologies (e.g., data collection, sensory requirements), balancing the commercial and developmental objectives and the welfare needs of children. Prior work [21] highlights adults' roles in this process: as users, proxies, experts, and facilitators. This research provides valuable insights into how parents can be actively involved in the design process for children's VR use. Additionally, raising public awareness and establishing robust ethical guidelines or regulatory frameworks are crucial to aligning technological advancements in VR with child welfare. Public actions and choices in the digital environment have significant consequences for politics, markets, regulatory effectiveness, equity, and the direction of socio-technical change [51].

5.2 Design and Research Implications of Children's VR Usage

5.2.1 Anticipating and Shaping the Health, Developmental and Societal Impacts of Children with VR Exposure. Concerns about the impacts of VR on children's health, development, and social connections (Sections 4.2.2 and 4.2.1) necessitate a thoughtful approach to the design and research of VR technologies, leading to several key implications. First, longitudinal studies are essential to understand the long-term impacts of VR on children's physical, cognitive, and social development. Although there are many studies investigating the impact of children's VR usage on their health (e.g., motion sickness and visual impact [15, 65, 81]), most of the work focused on short-term impact from one or two times study in lab environment. Future research should investigate the long-term impact of VR on children's health and well-being. Notably, when performing long-term study in a more natural setting, researchers must carefully consider the effects and interactions with other digital and technology usage that may interfere with VR.

Second, VR technology and content should be designed to support children's physical, cognitive, and emotional development and contribute positively to a child's growth. For example, one way to promote health is to encourage more physical activity and incorporate VR experiences' haptic capabilities. This could include sports and fitness applications or games that require physical movement, thus promoting a healthy balance between virtual and physical play (e.g., [6, 12]). Another example is that VR systems should incorporate features that promote social interactions between the virtual and physical worlds. This can be achieved by designing multiplayer applications that encourage collaboration and communication between the two worlds (e.g., mixed reality [66]) or by integrating real-world tasks into the VR experience to foster community bonds and peer connections.

Moreover, developing child-friendly questionnaires for the assessment of VR for children is crucial. For example, one study adapted the motion sickness questionnaire [47] by using the Wong-Baker FACES Pain Rating Scale [86] to create a pediatric questionnaire. Yarosh et al. [87] proposed an affective benefits and costs of communication questionnaire to understand communication media, including VR. This questionnaire was adapted for children by simplifying the wording and making the questions clearer; it also used the recommended Likert-type scale focused on the frequency of events within a specific period[20], rather than a scale based on agreement (e.g., from 'never' to 'always', instead of 'strongly disagree' to 'strongly agree'). Future research should refine and expand assessment tools specifically tailored for children in VR environments. This includes creating methodologies that accurately capture and interpret children's unique cognitive, emotional, and physical responses to VR experiences.

5.2.2 Creating Children-Centric VR Ecosystem for Safety, Privacy, and Inclusivity. In sections 4.2.3 and 4.2.4, we identified crucial aspects of ensuring safety, privacy, and inclusivity in the VR ecosystem. The extensive tracking and recording of children's interactions

in VR pose significant challenges in protecting their rights, exacerbated by the lack of comprehensive regulations and mechanisms to support children's autonomy [58, 76]. Responding to these challenges, we propose implications for children-centric VR ecosystem for safety, privacy, and inclusivity.

First, future research should promote children's data literacy in VR contexts. This involves educating youths about data processing, privacy, and confidentiality while instilling a deep understanding of data flows and life cycles [27]. Calls for mainstreaming media literacy education and raising awareness are complemented by urging policymakers to improve data controllers' public-facing mechanisms, including transparency, accountability, and redress. Prior work in this area includes [51, 52], which conducted focus group discussions with children aged 11-16, in addition to interviews with parents and educators, using real-life scenarios to stimulate conversation on digital opportunities, risks, and practical dilemmas. Bilstrup et al. explored ways to design tools and activities to support children's data literacy [16]. Further research into tools to support VR-specific data literacy is necessary. Following the design principles to support data literacy in children [16], tool developers should prioritize making those data (e.g., biometric and behavioral data collected in VR) emotionally engaging and personal and offering contextualized data representations to facilitate reflection.

Second, develop child-friendly authentication methods in VR to provide children with the ability to keep their own data secured. Current symbolic input methods for authentication in VR (using text, figures, or characters) are challenging for young children due to the development of their fine motor skills and memory retention capabilities [55]. Context-based authentication methods, such as selecting sequences of objects in VR environments [30] or choosing directions in virtual scenes [39], show promise for younger users. These methods may increase initial entry time but offer greater potential for secure and accessible authentication for children in VR. Besides context-based authentication, future research can also include exploring biometric authentication techniques, such as voice recognition, which are more intuitive for children.

Third, implement child-centered systems to promote online safety and inclusivity. This encompasses strategies like developing user-friendly reporting tools with clear instructions and immediate feedback mechanisms to simplify the process for children to report inappropriate content or behavior. Emphasizing diverse content representation is also vital, ensuring that a wide range of cultures, abilities, and genders are reflected in VR content to foster an inclusive environment. Many studies have been done to improve VR accessibility (e.g., assisting low vision [88] and deaf people [40]). When it comes to children, additional attention are necessary to account for variations in motor skills development and attention span, as children exhibit diverse developmental stages.

5.2.3 Developing Flexible and Collaborative Parental Involvement Mechanisms. Our findings in section 4.3.2 show parental supervision and control is important to guide children's technology use and teach them how to be responsible with their devices. Besides, careful design of parental involvement mechanisms can serve as important strategies to reduce concerns of health risk, social isolation and security issues. More flexibility and collaboration are needed in the design of parental involvement mechanisms.

First, develop tools that enhance parental involvement by offering flexible data access, screen time, content, and activity supervision and control. A major challenge with VR is the difficulty for parents to monitor their children's immersive environment. Current solutions, such as the casting feature, offer limited oversight capabilities. There is a clear need for monitoring tools that are intuitive and non-intrusive, flexible in both time and methods to cater to various contexts and schedules. For instance, developing systems that allow parents to monitor their child's VR activities in real-time (synchronously) and also view recorded sessions (asynchronously) for later assessment would be beneficial.

Second, provide collaborative content control between parents and children. Numerous existing tools, such as Bark [9] and Aura [5] for phones and PCs, assist parents in limiting their children's exposure to inappropriate content. However, these tools often rely solely on rules set by parents or companies, neglecting the fact that parents and children may have differing content preferences and VR expectations. This discordance is highlighted in Section 5.1. Previous research [46] has noted children's desire for less parental control over their technology use, advocating for more autonomy in their interactions with devices. Excluding children from the decision-making process about content and usage restrictions can lead to misunderstandings about these limitations and potential conflicts in technology usage. Prior works have explored joint oversight involving children [3, 37]. This strategy engages children in learning about digital rules and provides parents with a control mechanism that aligns with their concerns. Future research should focus on expanding this collaborative approach to content control, ensuring that both parents' concerns and children's preferences are balanced.

6 CONCLUSION

In order to investigate ethical issues and design considerations of children (7-13) using VR, we utilized anticipatory methods to create scenarios and conducted surveys and interviews to collect primary data from 67 children and 55 parents. Our analysis of both quantitative survey data and qualitative interview responses highlighted four ethical concerns: the erosion of physical community bonds, potential long-term health and developmental impacts, risks to safety and privacy, and issues related to equity and inclusion. Additionally, we identified two key considerations for the design and implementation of VR for youth: promoting open communication to recognize both the benefits and risks, and supporting parental supervision and control. Our research contributes to the empirical understanding of VR ethics for children and offers valuable design and research considerations for the utilization of VR by children.

7 SELECTION AND PARTICIPATION OF CHILDREN

We received IRB permission to work with the Driven to Discover Research Facility on the fairgrounds at the Minnesota State Fair. A total of 67 children (primarily in the 7-13 age range) and their guardians participated in this study. Participant recruitment for this study was conducted as families with children passed by the research facility on the fairgrounds. The study methodology involved an introduction to VR via an exploration system, followed by a

scenario-based survey and semi-structured interview, focusing on VR's implications in family, educational, and healthcare contexts.

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REFERENCES

[1] 2023. Supplemental Meta Platforms Technologies Terms of Service. https://www.meta.com/legal/supplemental-terms-of-service/
[2] 2024. Safer VR spaces for your family on Meta Quest.
[3] Mamtaj Akter, Amy J Godfrey, Jess Kropczynski, Heather R Lipford, and Pamela J Wisniewski. 2022. From Parental Control to Joint Family Oversight: Can Parents and Teens Manage Mobile Online Safety and Privacy as Equals? *Proceedings of the ACM on Human-Computer Interaction* 6, CSCW1 (2022), 1–28.
[4] Paola Araiza-Alba, Therese Keane, and Jordy Kaufman. 2022. Are we ready for virtual reality in K–12 classrooms? *Technology, Pedagogy and Education* 31, 4 (2022), 471–491.
[5] Aura. 2023. *Aura Parental Controls.* https://buy.aura.com
[6] Myeong-Hun Bae. 2023. The Effect of a Virtual Reality-Based Physical Education Program on Physical Fitness among Elementary School Students. *Iranian Journal of Public Health* 52, 2 (2023), 371.
[7] Jakki O Bailey and Jeremy N Bailenson. 2017. Considering virtual reality in children's lives. *Journal of Children and Media* 11, 1 (2017), 107–113.
[8] Jakki O. Bailey and Isabella Schloss. 2023. "Awesomely freaky!" The impact of type on children's social-emotional perceptions of virtual reality characters. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–10. https://doi.org/10.1145/3544548.3581501
[9] Bark Technologies, Inc. 2023. *Bark - Internet Safety for Kids.* https://www.bark.us
[10] Marguerite Barry, Kevin Doherty, Jose Marcano Belisario, Josip Car, Cecily Morrison, and Gavin Doherty. 2017. mHealth for Maternal Mental Health: Everyday Wisdom in Ethical Design. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17)*. Association for Computing Machinery, New York, NY, USA, 2708–2756. https://doi.org/10.1145/3025453.3025918
[11] Valentin Bauer, Ali Adjorlu, Linnea Bjerregaard Pedersen, Tifanie Bouchara, and Stefania Serafin. 2023. Music Therapy in Virtual Reality for Autistic Children with Severe Learning Disabilities. In *Proceedings of the 29th ACM Symposium on Virtual Reality Software and Technology (VRST '23)*. Association for Computing Machinery, New York, NY, USA, 1–9. https://doi.org/10.1145/3611659.3615713
[12] Dawid Bedrunka, Katarzyna Buchta, Patryk Szary, Katarzyna Maniakowska, Pawel Kiper, Anna Rutkowska, and Sebastian Rutkowski. 2019. The effect of virtual reality exercise on physical fitness. *Medical Rehabilitation* 23 (2019), 4–9.
[13] Linda Liska Belgrave and Kapriskie Seide. 2019. Coding for grounded theory. *The SAGE handbook of current developments in grounded theory* (2019), 167–185.
[14] Marcella Bellani, L Fornasari, Luca Chittaro, and P Brambilla. 2011. Virtual reality in autism: state of the art. *Epidemiology and psychiatric sciences* 20, 3 (2011), 235–238.
[15] Stine Hansen Bendiksen and Lisa Jørgensen. 2016. *Balancing the virtual reality experience: A study of human reactions with the Oculus Rift DK2.* B.S. thesis.
[16] Karl-Emil Kjær Bilstrup, Magnus Høholt Kaspersen, Mille Skovhus Lunding, Marie-Monique Schaper, Maarten Van Mechelen, Mariana Aki Tamashiro, Rachel Charlotte Smith, Ole Sejer Iversen, and Marianne Graves Petersen. 2022. Supporting Critical Data Literacy in K-9 Education: Three Principles for Enriching Pupils' Relationship to Data. In *Proceedings of the 21st Annual ACM Interaction Design and Children Conference* (Braga, Portugal) *(IDC '22)*. Association for Computing Machinery, New York, NY, USA, 225–236. https://doi.org/10.1145/3501712.3530783
[17] Lindsay Blackwell, Nicole Ellison, Natasha Elliott-Deflo, and Raz Schwartz. 2019. Harassment in Social Virtual Reality: Challenges for Platform Governance. *Proc. ACM Hum.-Comput. Interact.* 3, CSCW, Article 100 (nov 2019), 25 pages. https://doi.org/10.1145/3359202
[18] Dana Blanco, Rachel M Roberts, Anne Gannoni, and Steve Cook. 2023. Assessment and treatment of mental health conditions in children and adolescents: A systematic scoping review of how virtual reality environments have been used. *Clinical Child Psychology and Psychiatry* (2023), 13591045231204082.
[19] Marianne Boenink, Tsjalling Swierstra, and Dirk Stemerding. 2010. Anticipating the interaction between technology and morality: A scenario study of experimenting with humans in bionanotechnology. *Studies in ethics, law, and technology* 4, 2 (2010).
[20] N Borgers and JJ Hox. 2000. Reliability of responses in questionnaire research with children. In *fifth international conference on logic and methodology, Cologne, Germany.*
[21] Peter Börjesson, Wolmet Barendregt, Eva Eriksson, and Olof Torgersson. 2015. Designing technology for and with developmentally diverse children: a systematic literature review. In *Proceedings of the 14th international conference on interaction design and children.* 79–88.
[22] Philip Brey. 2017. Ethics of emerging technology. *The ethics of technology: Methods and approaches* (2017), 175–191.
[23] Philip AE Brey. 2012. Anticipatory ethics for emerging technologies. *NanoEthics* 6, 1 (2012), 1–13.
[24] Julie Carmigniani, Borko Furht, Marco Anisetti, Paolo Ceravolo, Ernesto Damiani, and Misa Ivkovic. 2011. Augmented reality technologies, systems and applications. *Multimedia Tools and Applications* 51, 1 (Jan. 2011), 341–377. https://doi.org/10.1007/s11042-010-0660-6
[25] Yingying Chu. 2022. The Application of VR Technology in Traditional Culture and Art Immersive Teaching for Chinese Children. In *Proceedings of the 13th International Conference on Education Technology and Computers* (Wuhan, China) *(ICETC '21)*. Association for Computing Machinery, New York, NY, USA, 99–104. https://doi.org/10.1145/3498765.3498780
[26] Lachlan D. Urquhart and Peter J. Craigon. 2021. The Moral-IT Deck: a tool for ethics by design. *Journal of Responsible Innovation* 8, 1 (2021), 94–126.
[27] Aayushi Dangol and Sayamindu Dasgupta. 2023. Constructionist approaches to critical data literacy: A review. In *Proceedings of the 22nd Annual ACM Interaction Design and Children Conference.* 112–123.
[28] Cristina Fiani, Robin Bretin, Mark Mcgill, and Mohamed Khamis. 2023. Big Buddy: Exploring Child Reactions and Parental Perceptions towards a Simulated Embodied Moderating System for Social Virtual Reality. In *Proceedings of the 22nd Annual ACM Interaction Design and Children Conference (IDC '23)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3585088.3589374
[29] Guo Freeman, Samaneh Zamanifard, Divine Maloney, and Dane Acena. 2022. Disturbing the Peace: Experiencing and Mitigating Emerging Harassment in Social Virtual Reality. *Proc. ACM Hum.-Comput. Interact.* 6, CSCW1, Article 85 (apr 2022), 30 pages. https://doi.org/10.1145/3512932
[30] Ceenu George, Mohamed Khamis, Daniel Buschek, and Heinrich Hussmann. 2019. Investigating the third dimension for authentication in immersive virtual reality and in the real world. In *2019 ieee conference on virtual reality and 3d user interfaces (vr).* IEEE, 277–285.
[31] Jonathan Gershon, Elana Zimand, Melissa Pickering, Barbara Olasov Rothbaum, and Larry Hodges. 2004. A pilot and feasibility study of virtual reality as a distraction for children with cancer. *Journal of the American Academy of Child and Adolescent Psychiatry* 43, 10 (Oct. 2004), 1243–1249. https://doi.org/10.1097/01.chi.0000135621.23145.05
[32] Kosar Ghaddaripouri, Seyyedeh Fatemeh Mousavi Baigi, Nazanin Noori, and Mohammad Reza Mazaheri Habibi. 2022. Investigating the effect of virtual reality on reducing the anxiety in children: A systematic review. *Frontiers in Health Informatics* 11, 1 (2022), 114.
[33] José Gutiérrez-Maldonado, Brenda K Wiederhold, and Giuseppe Riva. 2016. Future directions: how virtual reality can further improve the assessment and treatment of eating disorders and obesity. *Cyberpsychology, Behavior, and Social Networking* 19, 2 (2016), 148–153.
[34] Daniel A Guttentag. 2010. Virtual reality: Applications and implications for tourism. *Tourism management* 31, 5 (2010), 637–651.
[35] M. Hankala, M. Kankaanranta, K. Kepler-Uotinen, R. Rousi, and S. Mehtälä. 2017. Towards a scenario of virtual mental health environments for school-aged children. In *Proceedings of the 21st International Academic Mindtrek Conference (AcademicMindtrek '17)*. Association for Computing Machinery, New York, NY, USA, 239–242. https://doi.org/10.1145/3131085.3131100
[36] Kristan Harris and Denise Reid. 2005. The influence of virtual reality play on children's motivation. *Canadian journal of occupational therapy* 72, 1 (2005), 21–29.
[37] Yasmeen Hashish, Andrea Bunt, and James E Young. 2014. Involving children in content control: a collaborative and education-oriented content filtering approach. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* 1797–1806.
[38] Juan Pablo Hourcade, Elizabeth Bonsignore, Tamara Clegg, Flannery Currin, Jerry A Fails, Georgie Qiao Jin, Summer R Schmuecker, and Lana Yarosh. 2023. Ethics of Emerging Communication and Collaboration Technologies for Children. In *Companion Publication of the 2023 Conference on Computer Supported Cooperative Work and Social Computing.* 560–562.
[39] Yuxuan Huang, Danhua Zhang, and Evan Suma Rosenberg. 2023. DBA: Direction-Based Authentication in Virtual Reality. In *2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW).* IEEE, 953–954.

[40] Dhruv Jain, Sasa Junuzovic, Eyal Ofek, Mike Sinclair, John R. Porter, Chris Yoon, Swetha Machanavajhala, and Meredith Ringel Morris. 2021. Towards Sound Accessibility in Virtual Reality. In *Proceedings of the 2021 International Conference on Multimodal Interaction* (Montréal, QC, Canada) *(ICMI '21)*. Association for Computing Machinery, New York, NY, USA, 80–91. https://doi.org/10.1145/3462244.3479946

[41] Qiao Jin, Yu Liu, Svetlana Yarosh, Bo Han, and Feng Qian. 2022. How Will VR Enter University Classrooms? Multi-stakeholders Investigation of VR in Higher Education. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*. Association for Computing Machinery, New York, NY, USA, 1–17. https://doi.org/10.1145/3491102.3517542

[42] Qiao Jin, Yu Liu, Ye Yuan, Lana Yarosh, and Evan Suma Rosenberg. 2020. VWorld: an immersive VR system for learning programming. In *Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts (IDC '20)*. Association for Computing Machinery, New York, NY, USA, 235–240. https://doi.org/10.1145/3397617.3397843

[43] Andrew Johnson, Thomas Moher, and Stellan Ohlsson. 1999. The round earth project: collaborative VR for elementary school kids. In *International Conference on Computer Graphics and Interactive Techniques: ACM SIGGRAPH 99 Conference abstracts and applications*, Vol. 8. 90–93.

[44] Robert Kail. 2000. Speed of information processing: Developmental change and links to intelligence. *Journal of School Psychology* 38, 1 (2000), 51–61.

[45] Polyxeni Kaimara, Andreas Oikonomou, and Ioannis Deliyannis. 2022. Could virtual reality applications pose real risks to children and adolescents? A systematic review of ethical issues and concerns. *Virtual Reality* 26, 2 (2022), 697–735.

[46] Saba Kawas, Nicole S Kuhn, Kyle Sorstokke, Emily Bascom, Alexis Hiniker, and Katie Davis. 2021. When Screen Time Isn't Screen Time: Tensions and Needs Between Tweens and Their Parents During Nature-Based Exploration. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–14.

[47] Robert S Kennedy, Kay M Stanney, and William P Dunlap. 2000. Duration and exposure to virtual environments: sickness curves during and across sessions. *Presence: Teleoperators & Virtual Environments* 9, 5 (2000), 463–472.

[48] Ben Kenwright. 2018. Virtual reality: ethical challenges and dangers [opinion]. *IEEE Technology and Society Magazine* 37, 4 (2018), 20–25.

[49] Xin Lei, Andong Zhang, Bingcheng Wang, and Pei-Luen Patrick Rau. 2018. Can virtual reality help children learn mathematics better? The application of vr headset in children's discipline education. In *Cross-Cultural Design. Applications in Cultural Heritage, Creativity and Social Development: 10th International Conference, CCD 2018, Held as Part of HCI International 2018, Las Vegas, NV, USA, July 15-20, 2018, Proceedings, Part II 10*. Springer, 60–69.

[50] Alice Lin, Charles Chen, and Fuhua (Frank) Cheng. 2022. Improving the Emotional Health of Juveniles with VR Game. In *Proceedings of the 14th International Conference on Computer Modeling and Simulation (ICCMS '22)*. Association for Computing Machinery, New York, NY, USA, 194–200. https://doi.org/10.1145/3547578.3547608

[51] Sonia Livingstone. 2018. Children: a special case for privacy? *Intermedia* 46, 2 (2018), 18–23.

[52] Sonia Livingstone, Mariya Stoilova, and Rishita Nandagiri. 2019. Children's data and privacy online: growing up in a digital age: an evidence review. (2019).

[53] Melanie J. Maas and Janette M. Hughes. 2020. Virtual, augmented and mixed reality in K–12 education: a review of the literature. *Technology, Pedagogy and Education* 29, 2 (March 2020), 231–249. https://doi.org/10.1080/1475939X.2020.1737210 Publisher: Routledge _eprint: https://doi.org/10.1080/1475939X.2020.1737210.

[54] Divine Maloney, Guo Freeman, and Andrew Robb. 2020. It Is Complicated: Interacting with Children in Social Virtual Reality. In *2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*. 343–347. https://doi.org/10.1109/VRW50115.2020.00075

[55] Florian Mathis, John Williamson, Kami Vaniea, and Mohamed Khamis. 2020. Rubikauth: Fast and secure authentication in virtual reality. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–9.

[56] Rahel Maué and Rahel Flechtner. 2022. "Hopohopo": A Virtual Reality Awareness Application about Social Anxiety Disorder. In *Proceedings of Mensch und Computer 2022 (MuC '22)*. Association for Computing Machinery, New York, NY, USA, 420–424. https://doi.org/10.1145/3543758.3547550

[57] Joan McComas, Jayne Pivik, and Marc Laflamme. 1998. Current uses of Virtual Reality for children with disabilities. *Virtual environments in clinical psychology and neuroscience: Methods and techniques in advanced patient-therapist interaction* 58 (1998), 161.

[58] Tehila Minkus, Kelvin Liu, and Keith W Ross. 2015. Children seen but not heard: When parents compromise children's online privacy. In *Proceedings of the 24th international conference on World Wide Web*. 776–786.

[59] James H Moor. 2005. Why we need better ethics for emerging technologies. *Ethics and information technology* 7, 3 (2005), 111–119.

[60] Michael Muller. 2014. Curiosity, creativity, and surprise as analytic tools: Grounded theory method. In *Ways of Knowing in HCI*. Springer, 25–48.

[61] Elin Palm and Sven Ove Hansson. 2006. The case for ethical technology assessment (eTA). *Technological forecasting and social change* 73, 5 (2006), 543–558.

[62] Eli Peli. 1990. Visual issues in the use of a head-mounted monocular display. *Optical Engineering* 29, 8 (1990), 883–892.

[63] Katharina Petri, Kuno Feuerstein, Svea Folster, Florian Bariszlovich, and Kerstin Witte. 2020. Effects of Age, Gender, Familiarity with the Content, and Exposure Time on Cybersickness in Immersive Head-mounted Display Based Virtual Reality. *American Journal of Biomedical Sciences* (April 2020), 107–121. https://doi.org/10.5099/aj200200107

[64] Yehuda Pollak, Patricia L Weiss, Albert A Rizzo, Merav Weizer, Liron Shriki, Ruth S Shalev, and Varda Gross-Tsur. 2009. The utility of a continuous performance test embedded in virtual reality in measuring ADHD-related deficits. *Journal of Developmental & Behavioral Pediatrics* 30, 1 (2009), 2–6.

[65] Monika Pölönen, Toni Järvenpää, and Beatrice Bilcu. 2013. Stereoscopic 3D entertainment and its effect on viewing comfort: Comparison of children and adults. *Applied ergonomics* 44, 1 (2013), 151–160.

[66] Yvonne Rogers, Mike Scaife, Silvia Gabrielli, Hilary Smith, and Eric Harris. 2002. A conceptual framework for mixed reality environments: Designing novel learning activities for young children. *Presence* 11, 6 (2002), 677–686.

[67] Maria Roussos, Mark G Gillingham, and T Moher. 1998. Evaluation of an immersive collaborative virtual learning environment for K-12 education. In *Roundtable at the American Educational Research Association Annual Meeting, San Diego, CA.*

[68] Maria Roussou. 2004. Learning by doing and learning through play: an exploration of interactivity in virtual environments for children. *Computers in Entertainment (CIE)* 2, 1 (2004), 10–10.

[69] Maria Roussou, Martin Oliver, and Mel Slater. 2006. The virtual playground: an educational virtual reality environment for evaluating interactivity and conceptual learning. *Virtual reality* 10 (2006), 227–240.

[70] Charlotte Brasic Royeen. 1985. Adaptation of Likert scaling for use with children. *The Occupational Therapy Journal of Research* 5, 1 (1985), 59–69.

[71] Simon K Rushton and Patricia M Riddell. 1999. Developing visual systems and exposure to virtual reality and stereo displays: some concerns and speculations about the demands on accommodation and vergence. *Applied Ergonomics* 30, 1 (1999), 69–78.

[72] Samsung. 2023. *Samsung Gear VR Child Safety Information.* https://www.samsung.com/uk/support/mobile-devices/is-the-gear-vr-safe-for-children/#:~:text=This%20product%20should%20not%20be,critical%20period%20in%20visual%20development.

[73] Sofia Serholt and Wolmet Barendregt. 2016. Robots Tutoring Children: Longitudinal Evaluation of Social Engagement in Child-Robot Interaction. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (Gothenburg, Sweden) *(NordiCHI '16)*. Association for Computing Machinery, New York, NY, USA, Article 64, 10 pages. https://doi.org/10.1145/2971485.2971536

[74] Shahnaz Shahrbanian, Xiaoli Ma, N. Aghaei, N. Korner-Bitensky, Keivan Moshiri, and M. Simmonds. 2012. Use of virtual reality (immersive vs. non immersive) for pain management in children and adults: A systematic review of eviden ce from randomized controlled trials. https://www.semanticscholar.org/paper/Use-of-virtual-reality-(immersive-vs.-non-for-pain-Shahrbanian-Ma/2243177916644b0c509d94c59eac9cecfe5fd7db

[75] Shahnaz Shahrbanian, Xiaoli Ma, Najaf Aghaei, Nicol Korner-Bitensky, Keivan Moshiri, and Maureen J Simmonds. 2012. Use of virtual reality (immersive vs. non immersive) for pain management in children and adults: A systematic review of evidence from randomized controlled trials. *Eur J Exp Biol* 2, 5 (2012), 1408–22.

[76] Benjamin Shmueli and Ayelet Blecher-Prigat. 2010. Privacy for children. *Colum. Hum. Rts. L. Rev.* 42 (2010), 759.

[77] Dorothy Strickland, Lee M Marcus, Gary B Mesibov, and Kerry Hogan. 1996. Brief report: Two case studies using virtual reality as a learning tool for autistic children. *Journal of autism and developmental disorders* 26 (1996), 651–659.

[78] Xinyi Su and Shuo Yan. 2023. NoPhobiar: Designing A VR Game to Prevent Childhood Dark Phobia with Children and Stakeholders. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems (CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3544549.3585733

[79] Rosemary A Thompson et al. 2012. *Nurturing future generations: Promoting resilience in children and adolescents through social, emotional and cognitive skills*. Routledge.

[80] Lawrence Tychsen and Paul Foeller. 2018. Effects of immersive virtual reality viewing on young children: visuomotor function, postural stability and visually induced motion sickness. *Journal of American Association for Pediatric Ophthalmology and Strabismus {JAAPOS}* 22, 4 (2018), e5.

[81] Lawrence Tychsen and Paul Foeller. 2020. Effects of immersive virtual reality headset viewing on young children: Visuomotor function, postural stability, and motion sickness. *American journal of ophthalmology* 209 (2020), 151–159.

[82] Jessica Van Brummelen, Maura Kelleher, Mingyan Claire Tian, and Nghi Nguyen. 2023. What Do Children and Parents Want and Perceive in Conversational Agents? Towards Transparent, Trustworthy, Democratized Agents. In *Proceedings of the 22nd Annual ACM Interaction Design and Children Conference* (Chicago, IL, USA) *(IDC '23)*. Association for Computing Machinery, New York, NY, USA, 187–197. https://doi.org/10.1145/3585088.3589353

[83] Marieke Van Rooij, Adam Lobel, Owen Harris, Niki Smit, and Isabela Granic. 2016. DEEP: A biofeedback virtual reality game for children at-risk for anxiety. In *Proceedings of the 2016 CHI conference extended abstracts on human factors in computing systems*. 1989–1997.

[84] Aditya Vishwanath, Matthew Kam, and Neha Kumar. 2017. Examining Low-Cost Virtual Reality for Learning in Low-Resource Environments. In *Proceedings of the 2017 Conference on Designing Interactive Systems* (Edinburgh, United Kingdom) *(DIS '17)*. Association for Computing Machinery, New York, NY, USA, 1277–1281. https://doi.org/10.1145/3064663.3064696

[85] Theresa F. Wechsler, Martin Brockelmann, Konstantin Kulik, Felicitas M. Kopf, Martin Kocur, Michael Lankes, Andreas Mühlberger, and Christian Wolff. 2021. SpEYEders: Adults' and children's affective responses during immersive playful gaze interactions transforming virtual spiders. In *Extended Abstracts of the 2021 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '21)*. Association for Computing Machinery, New York, NY, USA, 74–79. https://doi.org/10.1145/3450337.3483463

[86] Donna L Wong and Connie M Baker. 2001. Smiling face as anchor for pain intensity scales. *Pain* 89, 2 (2001), 295–297.

[87] Svetlana Yarosh, Panos Markopoulos, and Gregory D Abowd. 2014. Towards a questionnaire for measuring affective benefits and costs of communication technologies. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*. 84–96.

[88] Yuhang Zhao, Edward Cutrell, Christian Holz, Meredith Ringel Morris, Eyal Ofek, and Andrew D Wilson. 2019. SeeingVR: A set of tools to make virtual reality more accessible to people with low vision. In *Proceedings of the 2019 CHI conference on human factors in computing systems*. 1–14.

A SCENARIOS

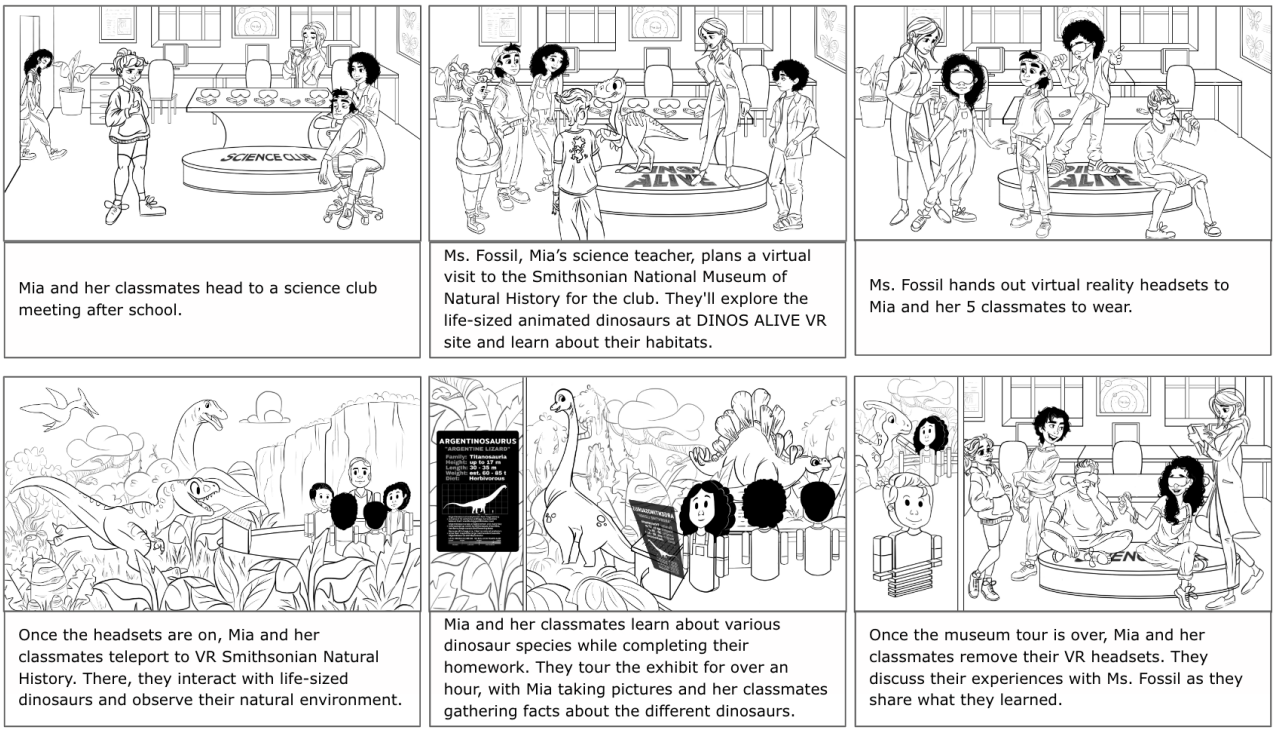

Figure 8: Education Utopia (EU): VR experiences augmenting an after-school STEM program.

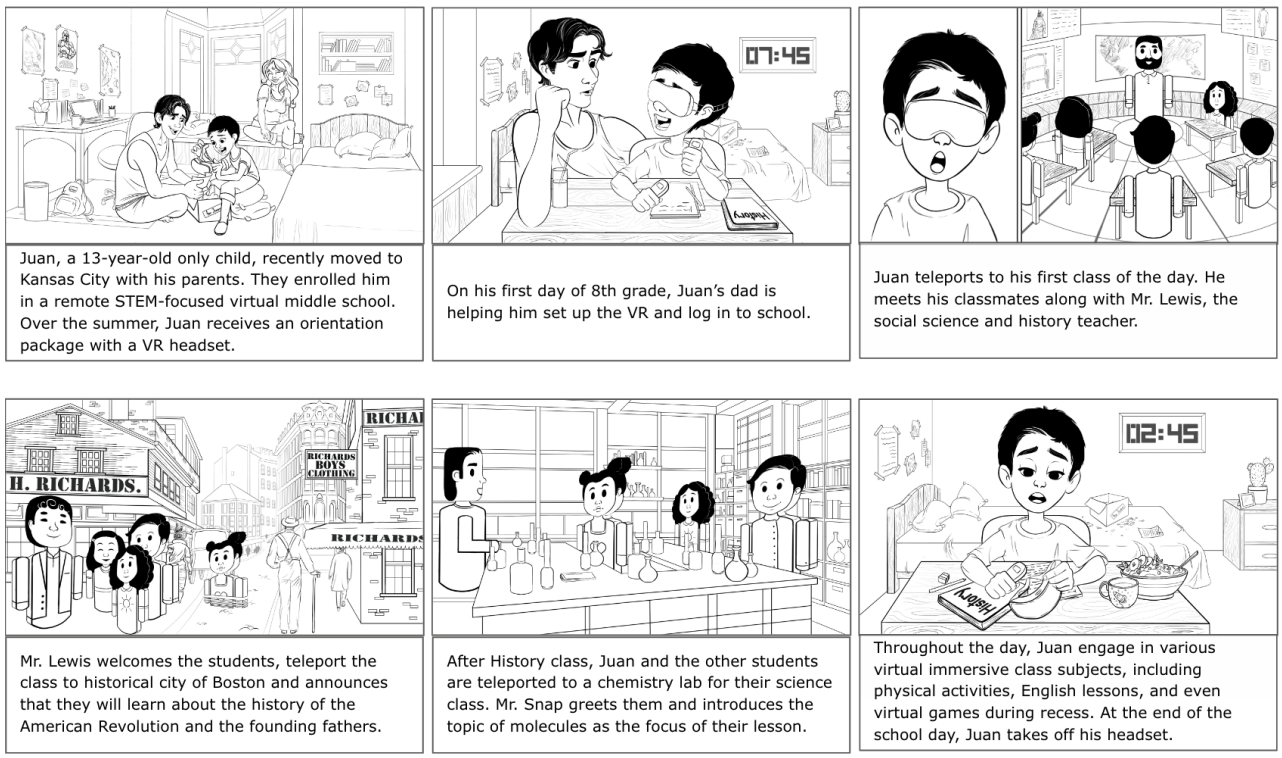

Figure 9: Education Dystopia (ED): VR shifts to education entirely within a virtual school setting.

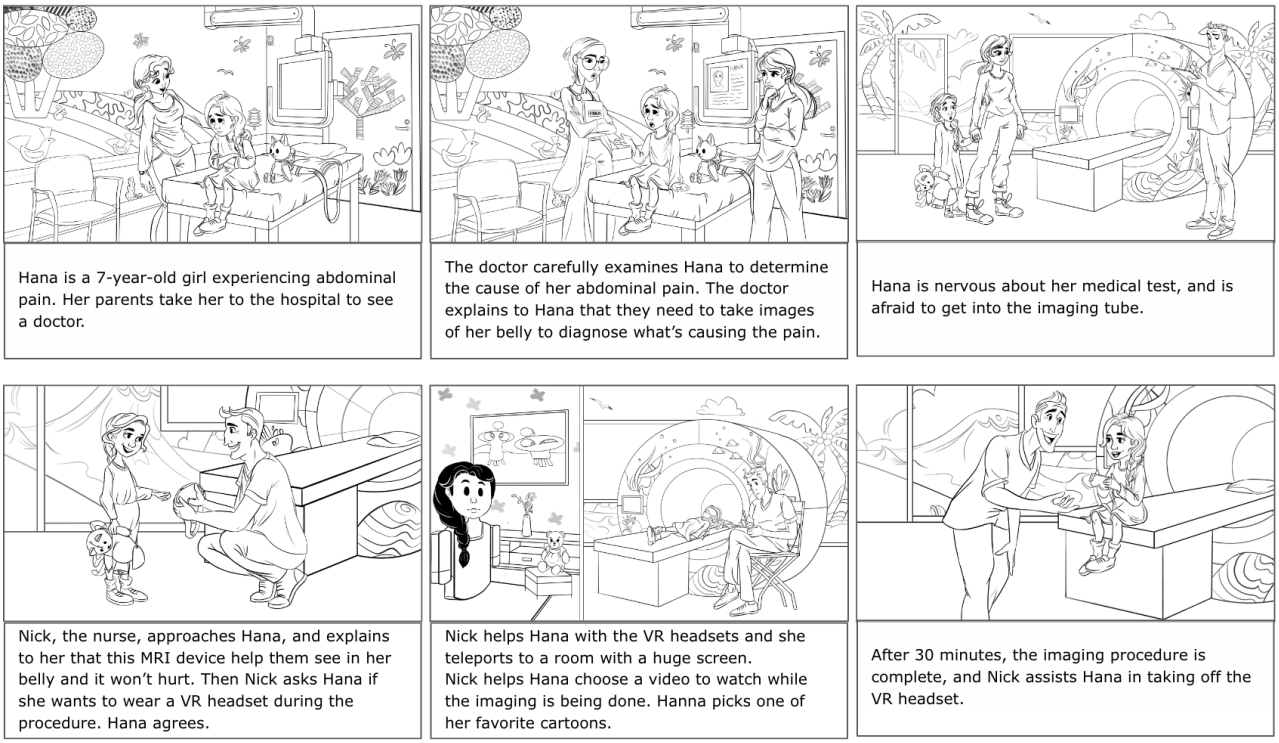

Figure 10: Healthcare Utopia (HU): Use of VR for distraction during children's medical MRI procedures.

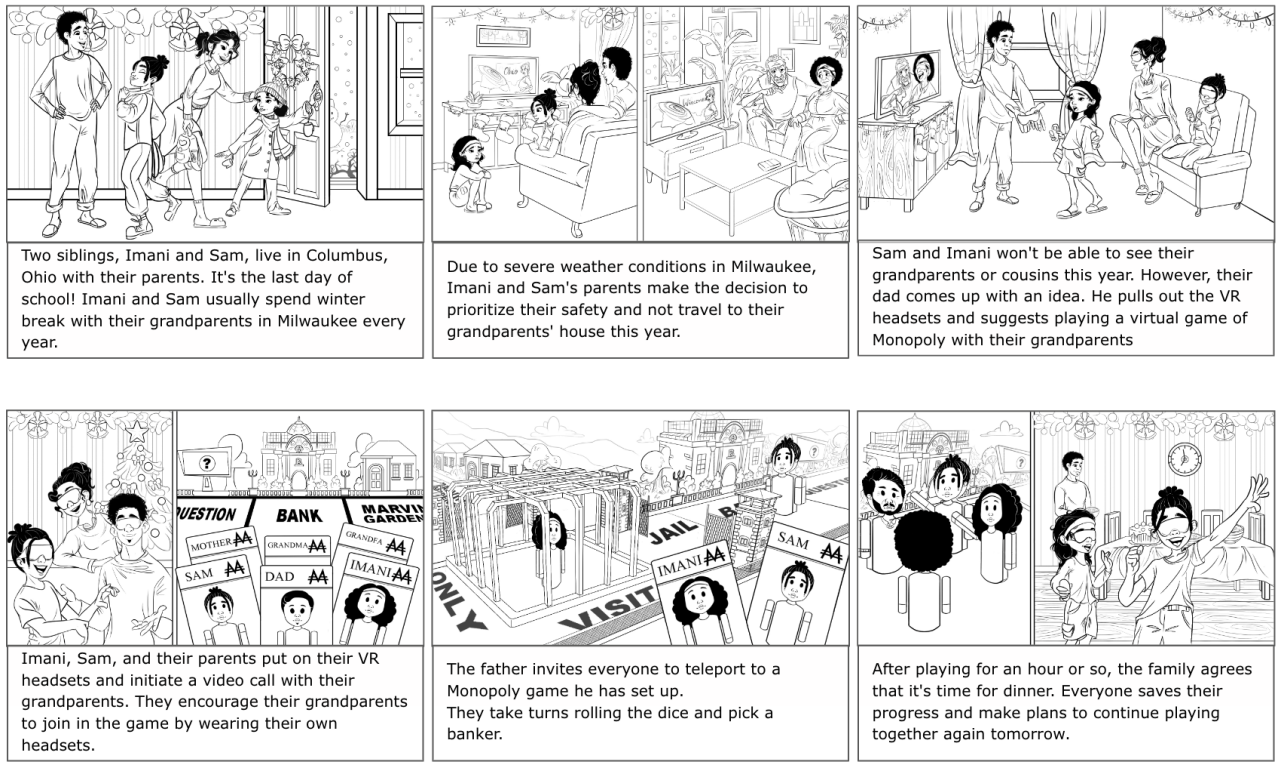

Figure 11: Family Utopia (FU): Family engaging together in VR gameplay.

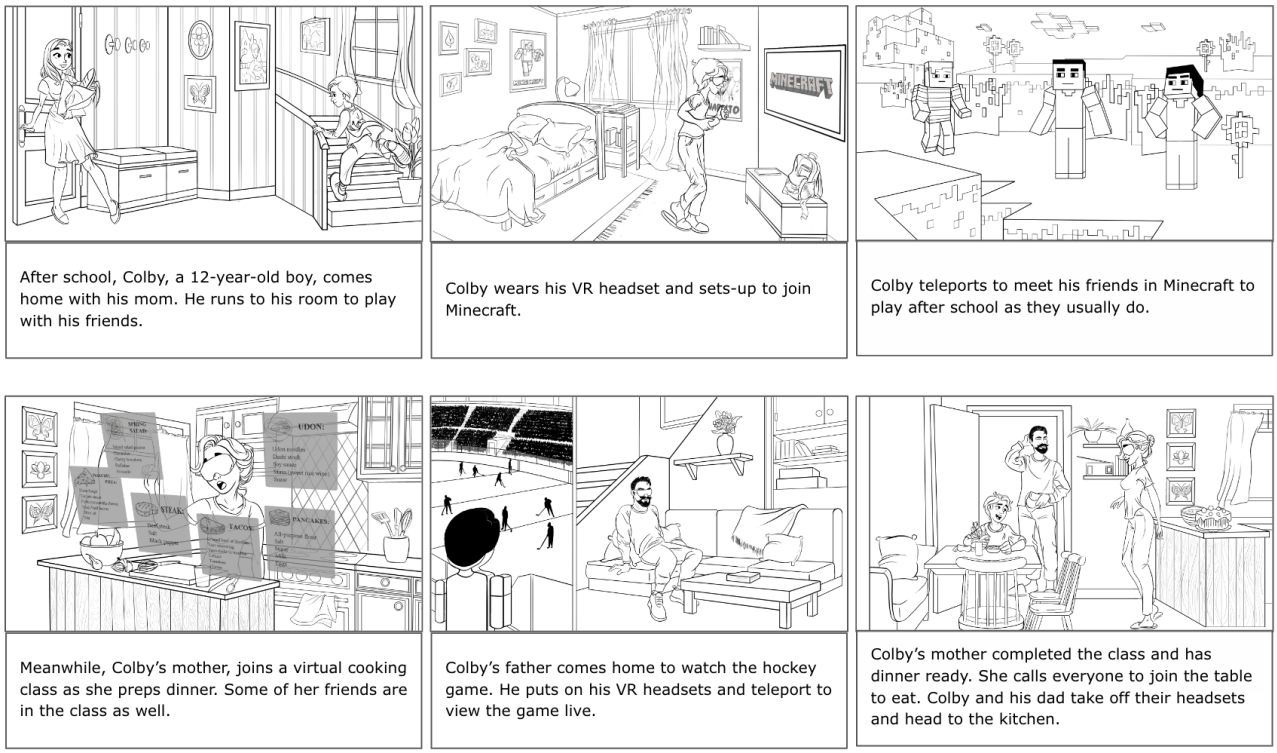

Figure 12: Family Dystopia (FD): Family members individually immersed in separate VR experiences while together physically.