AMERICAN PSYCHOLOGICAL ASSOCIATION

Technology, Mind, and Behavior

ISSN: 2689-0208

https://doi.org/10.1037/tmb0000066

SPECIAL COLLECTION: INNOVATIONS IN REMOTE INSTRUCTION

Accessibility of Educational Virtual Reality for Children During the COVID-19 Pandemic

Marijn Mado[1], Géraldine Fauville[2], Hanseul Jun[1], Elise Most[1], Carlyn Strang[3], and Jeremy N. Bailenson[1]
[1] Department of Communication, Stanford University
[2] Department of Education, Communication and Learning, University of Gothenburg
[3] Department of Sociology, Davidson College

This article provides an exploratory inquiry into children's use of educational virtual reality (VR) at home, thereby complementing prior experimental research about the effects of VR on children. In order to assess the potentially innovative role that VR can play in remote instruction, this study collected data from parents and legal guardians reporting on their children's VR use at home during the first wave of the shelter-in-place measures resulting from the coronavirus disease (COVID-19) pandemic. From April to July 2020, parents and legal guardians who own VR devices participated in a survey ($n = 311$), longitudinal follow-up surveys ($n = 60$), and in-depth interviews ($n = 20$). The results indicate how VR can function as an innovative tool for socioemotional learning in a situation of remote instruction by (a) enhancing school materials and (b) sparking conversations about current affairs. Additionally, the results highlight two main barriers obstructing children's learning with VR. First, VR technology is gendered and may hinder the usage of both women and girls. Second, educational content is hard to find and lacks contextualizing complementary materials. With regard to the first barrier, the authors argue that the gender issue should be addressed in order to make VR more accessible to all children. This article addresses the second barrier by providing a database of educational VR applications. Ultimately, educational VR applications should be complemented with contextualizing materials to reach VR's potential as an innovative learning tool.

Keywords: virtual reality, children, education, learning, gender

Virtual reality (VR) technologies create immersive virtual environments (IVEs) that simulate the actual world by tracking the movements of the user and responding with constantly updating visual and audio feedback. These IVEs perceptually surround the user and block out the actual world, as users for instance wear a head-mounted display[1] (HMD; Bailenson, 2018; Blascovich et al., 2002). VR is lauded for effectively blurring the line between the real and the virtual, thereby enabling children to explore remote locations, travel in time, become someone else, and practice skills—all the while in the comfort of their own home. As such, VR can be considered an innovative tool supporting children's education, especially in times of a global pandemic that requires remote instruction. At the same time, employing VR for children's education poses logistic, technological, and social challenges. This article investigates the role that VR can play in conditions of remote instruction, some of the challenges that may inhibit children's use of educational VR and thus the expected learning outcomes, and the potential ways in which educators, parents, and the VR community can address these challenges.

[1] For purposes of this study, VR will refer to HMD systems, as these are currently some of the most mainstream systems to access immersive virtual worlds (Bailenson, 2018).

Special Collection Editors: Rachel Flynn and Fran Blumberg
Action Editor: Fran Blumberg was the action editor for this article
ORCID iDs: Marijn Mado https://orcid.org/0000-0002-4491-4117; Hanseul Jun https://orcid.org/0000-0002-5114-4560; Elise Most https://orcid.org/0000-0001-8376-0125.
Funding: This research was supported by two National Science Foundation Grants (1800922 and 1906728) and a Knut och Alice Wallenberg Grant (20170440).
Disclosures: No competing financial interests exist. The work enclosed has not been published in whole or in part nor is it being considered for publication elsewhere. The data from the large sample survey as well as the surveys and interview template are publicly available at https://osf.io/z54tn/. For privacy reasons, the interview transcripts and longitudinal surveys data will not be made available.
Equal Contribution: Marijn Mado and Géraldine Fauville contributed equally to this work.
Study: The work was performed at Stanford University and the University of Gothenburg.

Contact Information: Correspondence concerning this article should be addressed to Marijn Mado, Department of Communication, Stanford University, McClatchy Hall, Building 120, 450 Serra Mall, Stanford, CA 94305-2050, United States or Géraldine Fauville, Department of Education, Communication and Learning, University of Gothenburg, Läroverksgatan 15, 41120 Göteborg, Sweden. Email: mnmado@stanford.edu or geraldine.fauville@gu.se

Educating Children With VR

Scholars commonly identify three different domains of learning: the cognitive (pertaining to knowledge and intellectual thinking), affective (making socioemotional judgments), and psychomotor (coordinating motor skills) domain (Anderson & Krathwohl, 2001; Hoque, 2016). Most of the experimental studies that assess the potential of VR to support children's learning find that VR is more effective than other learning methods when it comes to psychomotor skills training or socioemotional learning, while the results on cognitive learning are mixed (Queiroz et al., 2018).

As for affective learning, the review of 24 studies that assess the use of VR in K-12 education by Queiroz and colleagues finds that students report higher affective learning gains, such as increases in self-confidence and learning satisfaction, when using VR as opposed to other learning methods. Another element of socioemotional learning is being able to understand the perspective of others, which has been extensively studied with adult participants using VR. Martingano et al.'s (2021) recent meta-analysis of 43 of these studies found that VR experiences increase emotional empathy by arousing compassionate feelings, but does not improve cognitive empathy in the sense of imagining others' perspectives. Their findings indicate that in the case of adults, VR is the most effective in generating a rush of emotions that does not automatically lead to deeper reflective understanding (Martingano et al., 2021).

Whether VR is more effective for children's cognitive learning than other learning methods is still debated. Some studies show that VR generates higher learning gains than other media (Alhalabi, 2016; Rupp et al., 2019; Walshe & Driver, 2019), others indicate higher increases in learning for other media (Dede et al., 1997; Parong & Mayer, 2018), and some studies report no differences between conditions (Allcoat et al., 2021; Harrington et al., 2018; Makransky, et al., 2019). A possible explanation for these mixed effects of the efficacy of VR on cognitive conceptual learning is that the interactive VR experience may cause cognitive overload, thereby hampering the student's ability to process information (Mayer, 2017; Moreno & Mayer, 2002; Parong & Mayer, 2018).

Underaged children may face additional difficulties with VR as they feel more present in virtual environments (Sharar et al., 2007), and are more likely to confuse created reality from actual reality (Castaneda et al., 2018; Segovia & Bailenson, 2009). Particularly young children (6- and 7-year-olds) are prone to remembering the events in VR as if they happened in real life (Segovia & Bailenson, 2009), and more research is needed to assess the effects of VR on children's developing brains (Bailey & Bailenson, 2017). On top of this, most of the studies mentioned investigate the efficacy of VR for learning in comparison to other learning methods and are conducted in an experimental setting in schools, laboratories, or museums. None of these studies consider the dynamics of children's VR use at home.

VR in the Home

Already 21% of families in the U.S.A with children under the age of 18 owned a VR headset by 2017 (Aubrey et al., 2018) and in 2019 and 2020 together over 10 million VR headsets have been sold worldwide (Alsop, 2021); however, there is little known about children's VR use at home. Apart from home-based VR therapy interventions for children with cerebral palsy (Chen et al., 2015; Farr et al., 2021; Golomb et al., 2010), there are no studies assessing children's use of VR in the household. As such, this study is exploratory in nature and seeks to broadly map the landscape of children's VR use at home.

There is a wide range of work that explores how children use other types of media in the home, such as television (Mendoza, 2009), video games (Nikken & Jansz, 2006), or the Internet (Livingstone & Helsper, 2008). While the field of research on media at home is extremely broad, scholars have particularly focused on parental mediation practices (e.g., Clark, 2011; Nikken & Schols, 2015), class, race, and gender differences in children's media use (e.g., Lee et al., 2009; Woodard & Gridina, 2000), as well as the relation between learning and media use (e.g., Hofferth, 2010; Liebeskind et al., 2014). Considering the proliferation of sociological research on children's use of media at home, a discrepancy emerges between this abundance of studies and the lack of studies on VR at home. This study works toward filling this gap by exploring children's use of VR in the household.

Research Questions

In order to explore the innovative opportunities and challenges associated with using VR for children's remote education, the present study consists of data from the parents and legal guardians of children who used VR at home during the first months of the global health pandemic. This study poses the following research questions:

> RQ1: To what extent did the COVID-19 pandemic affect children's VR use at home?
>
> RQ2: How can VR play an innovative role in conditions of remote instruction?
>
> RQ3: What are some of the challenges that may inhibit children's remote learning with VR?

Methodology

This study recruited parents and legal guardians of children (0–17 years old) who owned at least one VR headset and asked them to participate in a large sample survey, longitudinal surveys, and/or in-depth interviews. This study did not include the children themselves but rather asked parents and legal guardians to report on their children's VR use, similar to the method used by Huber et al. (2018) in their study of children's media use at home. The methods were approved by Stanford University's Institutional Review Board. The surveys and interview template are available at https://osf.io/z54tn/.

Data Sources

Large Sample Survey

To recruit participants, information about the study was disseminated on various online platforms as well as by local schools and tech companies. Particularly, the online platforms included Twitter, 58 VR Facebook communities, and 30 VR Reddit communities as well as several newsletters and blog posts. In addition, the research team contacted approximately 250 heads of private schools along with some local schools. Furthermore, the leaders of approximately 45 VR and/or EdTech companies along with researchers in the field of VR were invited to participate in the study and asked to extend the invitation to their network.

The large sample survey was available from early May to early July, 2020. Participants did not receive compensation for completing this survey. The large sample survey took approximately 10 min to complete. Participants were asked a wide range of questions, such as demographics as well as to list all the VR experiences used by the children in their household. They were also asked about the extent to which their child(ren) engaged in educational VR activities (six-point Likert scale ranging from "Never" to "Very Frequently"). In order to measure the potential difference between VR usage prior to the pandemic and since the pandemic, we used a similar method to Cellini et al. (2020) by asking participants to provide the average time each of their children spent on VR per day both prior to the pandemic and since the pandemic. Participants replied to all survey questions separately for each of their children. In other words, a participant with three children replied to the same set of questions three times. This method of assessing each child in the family individually was suggested by Drouin et al. (2020). The data from the large sample survey are publicly available at https://osf.io/z54tn/.

Longitudinal Surveys

A subset of the large sample survey participants signed up for four longitudinal surveys that were administered between May to July, 2020. Each participant was asked to fill out one longitudinal survey every 2 weeks. The participants were compensated with a $30 Amazon gift card.

Each biweekly survey took approximately 8 min to complete and included open-ended prompts or questions such as the following: "Write any information related to your kids' use of VR in the last 2 weeks, in your own words." Respondents were also asked to report on their children's VR use in the last 2 weeks by describing which educational VR applications their children continued to use and which ones they ceased to use. Finally, they were asked to report on any additional change regarding their children's VR use.

Interviews

Participants who were taking the longitudinal surveys were invited to take part in an online interview. In addition, 3 weeks after launching the large sample survey, sign-ups for the longitudinal surveys were closed and replaced with online interview sign-ups. Women and men were selected alternately, until no more women were available for interviews. Transcripts of the interviews were created using the software Otter.ai, after which these transcripts were corrected by researchers and anonymized. Audio recordings were destroyed at the conclusion of the study. Excerpts from the interviews are available in the Results followed by a code from P1 to P20 for each interviewee along with their gender (woman, man). For privacy reasons, the interview transcripts and longitudinal surveys data will not be made available.

The interviews were conducted by the first two authors. The average interview lasted 38 min, with the shortest interview taking 21 min, and the longest 52 min. The questions asked during the interviews followed from the initial findings of the exploratory surveys and were amended based on previous interviews. In general, researchers first inquired whether and how the family's use of VR applications and time spent in VR had changed as a result of school closures. As the lockdown measures started on different dates in the different regions our interviewees lived, we asked them when their children's school closed and used this date as the start of the pandemic in that specific interview. The researchers then aimed to gain an understanding of the role that educational VR played in each family by asking participants about their children's use of and attitude toward the available educational VR applications. They also inquired about the process of looking for appropriate VR content. Finally, researchers attempted to understand participants' levels of comfort with VR technology by asking about their perception of its drawbacks, the appropriate age for children to begin using VR, and family dynamics while using VR.

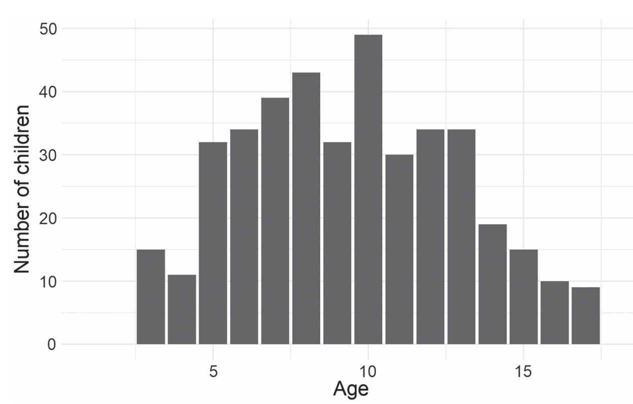
The analysis of the interview transcripts was based on thematic analysis, a method identifying and highlighting patterns or themes salient in the data (Attride-Stirling, 2001). In the present study, the themes of interest were based on how the participants discussed their children's VR use. Four authors on this article repeatedly read the data corpus while looking for patterns of interest. Next, the four researchers each annotated the transcripts with key words that described the children's VR usage, which allowed for the discovery of recurrent themes. The researchers presented and justified their own annotations to the other researchers to enable discussion and annotation comparisons.

Participants

Large Sample Survey

Three-hundred eleven participants (parents and legal guardians of children aged 0–17) completed the survey. Between the participants, 252 (81.0%) were located in the U.S.A., 12 (3.9%) in Canada, 11 (3.5%) in the U.K., and the remaining 36 (11.6%) were located in 22 other countries. Ninety-seven participants identified as women, while 213 identified as men, and one neither as woman nor man. By asking participants about their gender identity, this study focuses on the socially constructed gender of the participants, rather than the biological or physical sex of the participants (W.H.O., 2012). No data was collected concerning the race or ethnicity of the participants or their children. Together, participants reported the VR usages for 411 children (228 boys, 176 girls, and seven children with undeclared gender). The mean age of participants was 39.1 (SD = 7.8), and the mean age of children was 9.5 (SD = 3.6; Figure 1).

Figure 1
Distribution of the Childrens' Age



The average number of headsets owned by participants was 2.2 (SD = 2.0). About half of the children (n = 204) used VR for educational purposes "Occasionally," "Frequently," or "Very Frequently."

Longitudinal Surveys

One hundred seventy participants of the large sample survey signed up for the longitudinal surveys. Responses were removed from the final sample if participants had only completed one or two of the longitudinal surveys, or if they were considered spam responses by people who were likely filling out our surveys to obtain the gift card. The criteria for spam responses were the following: responses with almost exclusively "NA" or "none" answers, responses characterized by incoherent, strange, and repetitive phrases, as well as responses from different participants repeatedly including the exact same sentences and submitted within a few minutes of each other across multiple rounds of the survey. All the responses we identified as spam were submitted from email addresses made up of random numbers and letters. After checking the quality of the responses and removing low-quality responses, 60 participants completed three (n = 20) or four (n = 40) of these longitudinal surveys.

Interviews

Six women and 14 men agreed to be interviewed. Fifteen interviewees were located in the United States while five participants were located in four other countries (Canada, Indonesia, Mexico, and Turkey).

Results

The data collected in the large sample survey is employed to answer RQ1. Both RQ2 and RQ3 are addressed by drawing from the interview data.

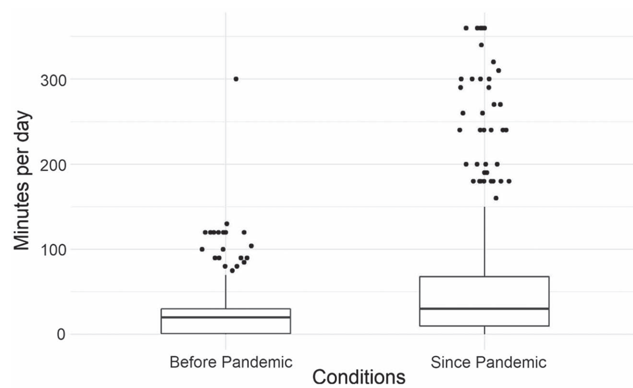
RQ1: To What Extent Does the COVID-19 Pandemic Affect Children's VR Use at Home?

In the exploratory large sample survey, participants were asked to quantify the time each of their children spent daily in VR prior to and since the pandemic. A Shapiro–Wilk normality test[2] (Shapiro & Wilk, 1965) indicated that the VR usage of the children significantly deviated from the normal distribution ($p < .001$). A nonparametric Wilcoxon-signed rank test revealed a significant difference between children's VR usage before and since the start of the pandemic (W = 891, $p < .001$). Before the start of the pandemic, the median of children's VR usage was 20 min per day (min: 0 min, IQR = 29 min, max: 300 min). The median of VR usage since the start of the pandemic was 30 min per day (min: 0 min, IQR: 58 min, max: 360 min). In other words, there has been a 50% increase in the median time children have spent using VR since the pandemic began (see Figure 2).

A closer look at the change in time children spent using VR (Figure 3) indicates that 71.5% of the represented children in this study (n = 294) increased their usage of VR since the start of the pandemic. About 25% of the children (n = 107) did not change their usage of VR while only 2.4% of the children (n = 10) decreased their usage. The data also highlighted that out of 80 children who did not use VR at all before the pandemic, 67 started using VR since the beginning of the pandemic, while only five children who used VR before the pandemic stopped using VR since the pandemic started.

Figure 2

Distribution of the Number of Minutes Per Day Parents Reported Their Children Spent Using Virtual Reality Before and Since the Pandemic Started



Note. The box plots present medians, interquartile ranges, and outliers.

The difference between usage before and since the pandemic was significant across ages. After sorting the children into the age groups 0–5, 6–11, 12–14, and 15–17 years old (following the Centers for Disease Control and Prevention, 2021, age demarcations for toddlers/preschoolers, middle childhood, young teens, and teenagers), a nonparametric Wilcoxon-signed rank test showed that there was a significant difference between usage before and since the start of the pandemic for each age group (for all four age groups: $p < .001$). The increase in children's VR usage was similar across all ages and was not significantly different for each gender.

RQ2: How Can VR Play an Innovative Role in Conditions of Remote Instruction?

Interviews with parents highlighted both the innovative role VR can play for children's education, as well as the challenges associated to using VR for children's education. The results relating to RQ2 and RQ3 are drawn from thematic analysis of the interview data (see Figure 4 for an outline of the themes).

Interviews with parents showed that VR is perceived as an effective and innovative tool which promotes children's socioemotional learning in the context of remote instruction. This is because of VR's ability to enable children to visit spatially distant museums and sites as well as its tendency to encourage conversations within the family and personal curiosity about current affairs.

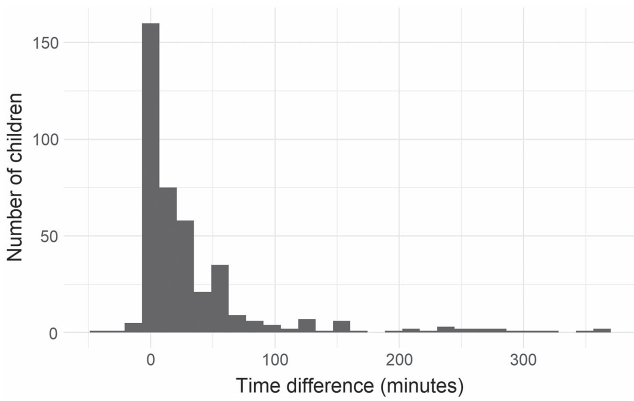
The affordances of VR allow children to travel in time and space, which has the capacity to illuminate school materials. One mother noted,

> My daughter takes Russian in school, and she's very interested in it . . . in the language, in the country, and so I gave her Wander, and said, 'Go to St. Petersburg or go to Moscow.' And we would pass the headset back and forth and we would do that. (P1 woman)

[2] All analyses were carried out in R Version 4.0.3.

Figure 3

Distribution of the Difference in the Number of Minutes Per Day Parents Reported Their Children Spent Using Virtual Reality (Minutes Before the Pandemic–Minutes Since the Pandemic Started)



Other participants mentioned that their children virtually visited the Frida Kahlo Museum in Mexico City (P2 woman), the moon (P5 man; P11 man), or revisited countries that they went to on vacation (P6 woman; P11 man).

In addition to exploring locations and encountering events as a way to support children's learning, VR can also be a tool to address current affairs. Our interviews showed that three of the most pressing current social events in 2020 were reflected in the material that children engaged with at home: the Black Lives Matter (BLM) movement, the refugee crisis, and the isolation that followed from the COVID-19 lockdown. By engaging with these events in VR, children became interested in the underlying mechanisms of the social situations, and initiated conversations within the family.

A mother recounted the moment that her teenage daughters became particularly invested in *Anne Frank House VR*. The mother is in the VR business herself: "I'll be honest with you, I'm immersed in technology from the morning, sun up until sun down" (P7 woman). She finds that her daughters are generally not as interested in VR as herself. However, the *Anne Frank House VR* experience resonated with her daughters' experiences of being stuck in the house during lockdown. She mentioned,

> It's definitely sparked different conversations in our house that we never would have had before. My daughter couldn't believe how small the house is that Anne Frank was in and she's like, 'Mom, you can't go anywhere.' I'm like, 'Yeah, that's the point' (P7 woman)

This daughter spent a considerable amount of time in the *Anne Frank House VR* experience, actively reading the information written on the walls, and asking questions about Anne Frank afterward. Her mother explained this otherwise surprising level of engagement and curiosity as the following:

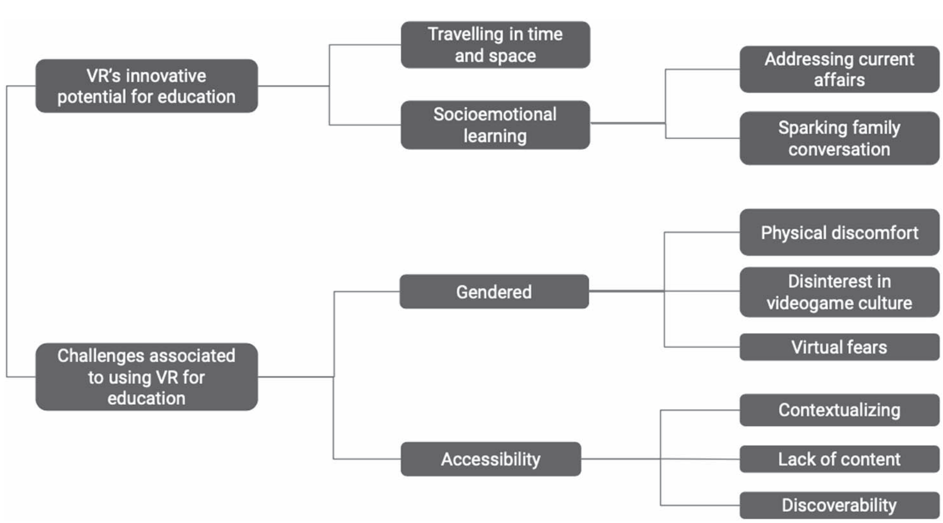
> Especially since we were all in isolation, and it was, you know, how much space we're grateful for. We have a very nice sized house, so we're okay. But it definitely puts things into perspective of what some other people might not be used to or have, and then what history was like as well. (P7 woman)

It appears that this VR experience could not have been timelier for these children, who had been stuck in their own house during the COVID-19 pandemic, and who found a direct way to empathize with the conditions of Anne Frank in the past.

A large social movement that shocked the entirety of the U.S.A. and beyond during the Spring and Summer of 2020, was the ignition of the BLM movement and widespread protests against police violence. A director of technology at a school district describes that as a response to the BLM events, he introduced the VR experience *Traveling While Black* to his 11-year-old son, which "has definitely sparked the ability to have some of those conversations and just say, 'Okay, do you understand what's going on? And why is it going on?'" (P8 man). This father described how this VR

Figure 4

Themes Resulting From the Thematic Analysis of the Interview Data



Note. Blocks on the left represent the two categories that divide the themes. Blocks in the middle form the main themes and blocks on the right are the subthemes. VR = virtual reality.

experience allowed his son to contextualize the events he sees on TV, by transporting him back into history in an immersive experience. He stated, "we couldn't be there for Martin Luther King's speech, but we can watch that speech. We can be as if we were there" (P8 man).

In addition to the BLM movement, the father and son had also watched *The Key*, which addresses the refugee crisis of the past decade. They watched at the same time, father on the Rift and son on the Quest, and talked about it afterward. The father noted about sharing this experience with his son,

> At the very end, you're standing essentially in a room that has been bombed out—but you can see out the windows. And his initial mindset was, 'Wow, what if people really had to live like that?' And I was like, 'No, it's not what if it's like that, this is real stuff. These are real people. This is really going on.' And kind of shifting some of that mindset and making sure that he understands. (P8 man)

This suggests how experiencing this VR activity may probe at a deeper emotional understanding of what it means to be a refugee. The comment of this father also hints at the importance of contextualizing the experience by discussing it before or after the experience. If the father would not have explained that the conditions his son saw in the VR story were realistic, the son would not have managed to learn and understand the situation properly.

Hence, VR has the potential to motivate children to discuss history and current affairs with their parents and siblings and therefore enhance socioemotional learning. This potential of VR is particularly valuable when remote instruction becomes the norm due to the COVID-19 pandemic.

RQ3: What Are Some of the Challenges That May Inhibit Children's Remote Learning With VR?

While the section above reveals VR's potential to promote children's socioemotional learning in remote instruction, our interviews also highlighted two challenges regarding accessibility in the use of VR for education. First, with regard to the technology itself, VR headsets are gendered which creates an equity issue. Second, in terms of content, appropriate educational material is hard to access.

Challenges Related to the Gender of VR Users

The interview findings speak to the gender bias that is prevalent in the community of VR users and reflected in our large sample survey participants, as significantly more men than women participated in this study. This section builds on the interview data to explicate the reasons why some women do not engage with VR technology. While many men indicated that their female partners were not interested in VR, women explained some of the obstacles inhibiting their use of VR technology. Out of the twenty interviews, 13 participants explicitly described a gendered VR world. These interviewees pointed out three mechanisms that hinder women's VR use.

Physical Discomfort. Several women indicated that they experience physical discomfort when using VR. A woman who mentioned suffering from headaches after using VR also noted similar symptoms experienced by her daughters: "Their first feedback is that it gives them a headache. That's for both of them" (P7 woman). Headaches are symptoms of visually induced motion sickness (Kennedy et al., 1993), which are referred to by a number of the mothers we interviewed. One mother told us, "I don't use it at all because I have severe motion sickness and I tried it once and I thought I was going to throw up" (P2 woman). In addition to motion sickness, women also experienced other discomforts, as one interviewee indicated that her daughter always needs to keep her long hair pulled back: "[the headset] pulls the hair out, she said that hurts" (P6 woman).

Disinterest in Video Game Culture. Besides these physical discomforts that follow from the gendered design of HMDs, women also appear less interested in VR due to their disinterest in video games and computer culture in general. Since they perceive VR as similar to video games, this disinterest seems to carry over, as one participant mentioned about his female partner: "She has never played any computer games. It's just an area that doesn't appeal to her" (P9 man). Another participant echoed this sentiment: "She doesn't play video games at all . . . she has probably tried VR when we first got it but she's not that interested" (P14 man). At times, this disinterest even turned into a negative attitude: "She is very biased against anything related to video games" (P18 man).

Virtual Fears. The factors constituting women's resistance to engage with VR exceeds their disinterest in computer or gaming culture. The particular technical qualities of VR headsets appear to lead to a set of fears for women. One participant mentioned how his wife is worried about the potential health issues that may accompany children's VR usage: "my wife is concerned about having all that kind of hardware very close to their brain" (P4 man). Other men described the fears that their wives have about disconnecting from physical reality: "She doesn't really like VR. She doesn't believe that it is something that a kid should be exposed to, that it untethers (sic) them from the real world" (P16 man). Similarly, another participant noted that his wife is afraid of VR: "She's against it . . . well against the 'being in other worlds part.' She is kind of scared of it" (P17 man). Those worries about the potential nefarious effects of VR technology can prevent women from trying out VR all together. As another husband noted, "My wife is a little freaked out by the whole thing . . . She's the only person that I've ever actually found so far that has been resistant to at least putting it on and seeing what it looks like" (P13 man).

Challenges Related to Context, Quantity, and Discoverability

While differential access to and comfort with VR technology generates an equity issue when using VR for children's education, the interviews also pointed to another obstacle to employing VR for supporting the educational endeavors of children. This section outlines the need for more educational VR material, strategies to locate and identify these VR activities, and support in scaffolding these activities as part of a broader educational module.

Contextualizing Educational Experiences. As becomes clear from the section above, VR could deepen children's engagement with school materials and their understanding of current affairs, when the virtual experience is supported by scaffolding conversations before and after. However, when such contextualization is lacking, children seem less inclined to reflect on the topic addressed. For example, a father told us that his son engaged with *The Key*, which addresses a topic covered in his civics class. Despite encountering the same content in school and in VR, the lack of scaffolding prevented him from seeing the overlap: “he never made the connection of ‘yeah, this is what we were talking about in the fall and look! I’m in a virtual environment,’ he never made that verbalization to me” (P20 man). Without complementary materials, the experience did not lead to further discussion:

> [The Key] didn’t inspire a whole lot of other questions or lead to more than some cursory conversations at the end. Virtual environments should be a gateway to, ‘hey! I need to read up some more on this. I’d like to get some books about this’ or ‘I want to try out some other apps about this or similar thing,’ or ‘we need to talk about this.’ (P20 man)

According to this father, in order for VR experiences to become “a gateway to wanting to learn more,” children need to be supported in their educational VR activities. Another father also wished that more support was available to contextualize VR activities, as he wished there was a “resource for parents to know what to expect, what conversations might happen” (P15 man).

Lack of Available Content. While the challenge with contextualization identified above assumes that educational VR applications are readily available, another challenge that emerged from the interviews concerns the lack of accessible educational content. About half of our interviewees mentioned that there are not enough available educational VR applications for children. A participant who has been part of the VR community professionally for more than 5 years commented on the lack of available content: “Well, educational content in VR? I haven’t seen quite a lot of it yet to be honest” (P17 man). Another participant, who described himself as “living and breathing VR,” echoed this opinion: “the educational side in VR is very, very limited. There’s just not much out there for kids to dive into” (P9 man). Yet another participant who shared the same views, highlighted the discrepancy in the evolution of the different fields in VR: “The education piece is always lagging behind when I look at how much VR is being used in industry right now, education is just even starting to scratch the surface” (P8 man). In some cases, this study encouraged participants to look for educational material, with little success: “Once this study started, it cued me to start looking around for what educational stuff there was for kids. And there’s a real dearth of that I found” (P15 man).

Discovering Content. Even though the limited availability of educational VR resources can in part be accounted for by the fact that few applications are available, the problem might also lie in the inability to find them. Our interviewees highlighted their difficulties with locating educational VR apps. Whereas one participant noted, “I think that discoverability can be difficult sometimes” (P4 man), another participant said, “I found the main difficulty was finding the educational apps ... I don’t even know how to search for just the educational content” (P12 man). One father eager to bring some educational content to his children’s VR activities echoed their opinion: “this stuff may all really exist somewhere outside of the channels that I’m used to looking for content on, right?” (P4 man). A mother asked us where she could get help to find and evaluate educational applications:

> Where would a parent like me find information about some of the educational VR experiences that exist? And is there any kind of a rating system going on with them as far as how good do people think they are? Have teachers looked at them and what do they say? (P10 woman)

Another participant commented on how difficult it is to find educational content for his 11-year-old daughter and also highlighted the need for the centralization of educational content that could be aligned with the formal curriculum:

> There isn’t a library or a place where we can go and say, ‘hey, this fits really well with your fourth grade California history content, this would be a good place to go.’ We got to dig around to find that stuff. (P11 man)

Thus, the main challenges with employing VR for children’s education appear to be the difficulties with discovering appropriate content and the need for complementary educational materials.

In order to address the challenge related to the accessibility of educational VR materials, and thereby support parents and educators with discovering content, this study provides an online database of 169 educational VR applications that were mentioned in the surveys or interviews at https://www.stanfordvr.com/edvrapps/. Each of these applications is coded for the school subject they relate to. Methods and results of this effort are outlined in Appendix.

Discussion

The issues of accessibility to educational VR that this study identifies are twofold. On the one hand, parents and legal guardians are at loss trying to find educational VR applications and are unable to find contextualized content. On the other hand, numerous women refrain from engaging with VR, due to a range of physical discomforts and other concerns. These accessibility issues need to be addressed in order for VR to meet its potential as an innovative learning tool for all children.

VR as an Innovative Learning Tool

The findings of this study suggest that VR could be a valuable tool in a situation of remote instruction, considering the significant increase in children’s VR use after the start of the COVID-19 lockdown measures. According to the participants, VR can play an important role in children’s socioemotional learning. In the household, VR illuminates school materials by allowing children to travel in time and space, and functions as an experiential conversation starter about history and current affairs, most notably the BLM movement, the refugee crisis, and the isolation following from COVID-19. As children are probed to discuss social issues with their families, as well as to ask questions about the suffering of others, opportunities for socioemotional learning arise. In this way, this study provides a sociological angle to the psychological body of work on perspective-taking in VR (e.g., Ahn et al., 2013; Banakou, et al., 2016; Kalyanaram et al., 2010).

Since this study focuses on the conditions that need to be in place for children to easily access educational VR, as will be further discussed below, this study contributes to prior work explicating the boundary conditions for using VR for socioemotional learning and eliciting empathy. In this way, this research builds upon studies that measure the duration of increases in empathy after the VR intervention (e.g., Banakou et al., 2016; Herrera et al., 2018), the extent to which perspective-taking in VR trains empathic skills that transfer to unrelated contexts (Mado et al., 2021), or the effect of contextualizing the VR experience with other mediums (Kalyanaraman et al., 2010).

As this study suggests that VR has the potential to function as an innovative tool supporting children's socioemotional and remote learning, it is worthwhile to acknowledge and address the challenges that inhibit educational VR for children.

Access to Educational Content

Parents and legal guardians highlight in the interviews the difficulties they face with finding appropriate educational VR content for their children. This may not be surprising since VR is still a relatively niche activity for children. The use and discoverability of educational VR content is evidently lower than for an established medium, such as television, as 80% of all U.S.A. children consume educational television on a weekly basis (Rideout, 2014).

In addition to discoverability, another issue with using educational VR for children is the need to contextualize the VR experience with supplementary materials or activities, such as informal discussions or further reading. The importance of contextualization was also shown by the socioemotional learning study of Kalyanaraman et al. (2010) which tested the efficacy of a VR experience that simulates schizophrenia. They found that participants became more empathic and had more positive attitudes toward people suffering from schizophrenia when the VR simulation was combined with a written perspective-taking task, as opposed to engaging in only one of those tasks. Participants who only engaged with the VR simulation felt significantly more distant to people suffering from schizophrenia. This led the authors to caution that virtual simulations work best when offered in tandem with complementary resources, in order to avoid counterproductive effects (Kalyanaraman et al., 2010). In a similar vein, Makransky et al. (2020) found that cognitive learning in VR is only more effective than learning with video when the experience was coupled with a generative learning task afterward. The authors suggest that the relative advantage of VR for learning science is dependent on the classroom integration (Makransky et al., 2020). These scholars echo this study's implications by indicating that VR is neither a magic bullet for socioemotional nor for cognitive learning and needs to be embedded in broader-learning activities in order to reach its innovative educational potential.

Gendered Design Decisions

Our findings reveal the gender bias in the VR community and show how this impacts women who have access to VR at home. The interviews revealed that many women are deterred from using VR either due to physical discomforts, negative attitudes toward gaming, or concerns about VR's immersive qualities. These inhibitive factors find their roots in the existing gender gap in the technology scene, which has been considered extensively in the literature.

It may come as no surprise that most of the participants and children in our study were male, considering that the technology industry is dominated by men (Wiener, 2020; Ullman, 1997), and that in general, women have indicated feeling less confident using technologies than men (Ausburn et al., 2009; He & Freeman, 2019; Huffman et al., 2013). Both of these trends can be accounted for by sociocultural gender norms that encourage men, rather than women, to engage with technologies. In education, people unconsciously attribute the field of STEM to men and the field of arts and humanities to women (Tranquada & Correia, 2018). Stereotypes thus play a role in preventing women from pursuing careers in STEM (O'Dea et al., 2018), despite the tendency of girls to obtain higher grades in STEM courses (Voyer & Voyer, 2014). According to an UNESCO (2017) report, only 35% of students in higher education STEM courses are female, and only 28% of researchers in STEM fields are women. This lack of female STEM scholars is also reflected in the field of VR research, as Peck et al. (2020) found that only 16% of the authors in the Proceedings of IEEE Virtual Reality Conferences from 2015 to 2019 were women, a significant underrepresentation of women. The gender norms that deter women's participation in the VR research and developing world, are likely to impact their VR use as well, as scholars have suggested that women tend to feel less comfortable and present in virtual environments (Felnhofer et al., 2012). These sociocultural factors help to explain why the women in this study appeared particularly concerned about their children's VR use, and were less comfortable and willing to try out the headset.

Aside from the sociocultural factors described above, biological differences also contribute to explaining the gender gap in VR. The women in our study who mentioned symptoms of visually induced motion sickness are no anomaly, as studies find that females are more likely than males to suffer from visual-induced motion sickness, such as cybersickness, when exposed to VR (De Leo et al., 2014; Jun et al., 2020; Hakkinen et al., 2002; Munafo et al., 2017; Stanney et al., 2003). The likely physiological cause of this gender-biased susceptibility to cybersickness was investigated by Stanney et al. (2020), who found that differences in interpupillary distance (IPD) drives the gender effect. The mainstream HMDs that are used to display VR content have a limited adjustable range of IPD. Women, who generally have smaller IPDs than men, are more likely to be unable to fit the headset to their morphology—the IPD of 35%–45% of women is incompatible with two of the mainstream headsets (HTC Vive and Oculus Rift S, respectively). The scholars found that women who could fit the headset to their IPD experienced similar rates of cybersickness as men (Stanney et al., 2020). As the authors point out in their title: "Virtual reality is sexist: but it does not have to be." Designing female-friendly headsets by including women as designers or testers (Peck et al., 2020) could go a long way to alleviate the gender gap in VR.

Prior work has pointed out the White male domination of the technology field, as well as the sexist and racist social implications of the technologies that are currently being designed, ranging from face recognition software to criminal risk assessment algorithms (Benjamin, 2019; Criado Perez, 2019). This study builds upon and contributes to this scholarly field by providing an account of the impact gender-biased technological design and sociocultural gender norms have on women's relationship to VR in their home. The hesitation of many mothers to engage with VR shows children that VR is most of all a male domain.

Limitations and Future Directions

This study also faces limitations. Due to the lack of prior research on VR use in the home, as well as the sudden appearance of lockdown measures as a response to the COVID-19 pandemic, the large sample survey and longitudinal surveys are exploratory in nature. As a result, this study was unable to systematically test predetermined hypotheses and instead sketches a broad picture of children's VR use at home. The exploratory surveys were invaluable in gathering a database of educational VR apps, guided the focus of the in-depth interviews, and helped to raise further research questions. One of the remaining questions in the context of remote instruction is whether children's *educational* use of VR increased during the pandemic, in addition to their overall use.

Furthermore, since the recruitment strategy depended on using existing professional networks, along with VR interest groups on different social media, newcomers in the world of VR may have been excluded from the sample. As a result, VR-savvy participants are overrepresented, which is indicated by the fact that the mean number of headsets per participant was over two. This average number of headsets also suggests that our sample represents people of particularly high socioeconomic status. As a consequence, we may have missed the particular hurdles that newcomers to the VR community or parents of lower socioeconomic status face, such as the costs of VR technology (which is becoming ever more affordable) and the technological know-how of setting up the technology and introducing it to children.

Other demographic variables that this study has not included are race, ethnicity, and disability. Since the people in our sample were predominantly White and able, we lacked variation in our sample to include these variables in our analysis. We encourage future studies to consider the role of race and other demographic factors in analyzing the accessibility to educational VR. Furthermore, since our approach, similarly to Huber et al. (2018), entailed collecting data from the parents and legal guardians on their children's use of VR, future research may benefit from including direct access to children's own experiences by observing or interviewing the children themselves.

References

Ahn, S. J., Le, A. M. T., & Bailenson, J. (2013). The effect of embodied experiences on self-other merging, attitude, and helping behavior. *Media Psychology*, *16*(1), 7–38. https://doi.org/10.1080/15213269.2012.755877

Alhalabi, W. S. (2016). Virtual reality systems enhance students' achievements in engineering education. *Behaviour & Information Technology*, *35*(11), 919–925. https://doi.org/10.1080/0144929X.2016.1212931

Allcoat, D., Hatchard, T., Azmat, F., Stansfield, K., Watson, D., & von Mühlenen, A. (2021). Education in the digital age: Learning experience in virtual and mixed realities. *Journal of Educational Computing Research*, *59*(5), 795–816. https://doi.org/10.1177/0735633120985120

Alsop, T. (2021). March 15). *Virtual reality headset unit sales worldwide from 2019 to 2024*. Statista. https://www.statista.com/statistics/677096/vr-headsets-worldwide/

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Longman.

Attride-Stirling, J. (2001) Thematic networks: An analytic tool for qualitative research. *Qualitative Research 1*(3), 385–405. https://doi.org/10.1177/146879410100100307

Aubrey, J. S., Robb, M. B., Bailey, J., & Bailenson, J. (2018). *Virtual reality 101: What you need to know about kids and VR*. Common Sense.

Ausburn, L. J., Martens, J., Washington, A., Steele, D., & Washburn, E. (2009). A cross-case analysis of gender issues in desktop virtual reality learning environments. *Journal of STEM Teacher Education*, *46*(3), 6.

Bailenson, J. (2018). *Experience on demand: What virtual reality is, how it works, and what it can do*. W.W. Norton.

Bailey, J. O., & Bailenson, J. N. (2017). Immersive virtual reality and the developing child. In F. C. Blumberg, & P. J. Brooks (Eds.), *Cognitive development in digital contexts* (pp. 181–200). Academic Press. https://doi.org/10.1016/B978-0-12-809481-5.00009-2

Banakou, D., Hanumanthu, P. D., & Slater, M. (2016). Virtual embodiment of white people in a black virtual body leads to a sustained reduction in their implicit racial bias. *Frontiers in Human Neuroscience*, *10*, Article 601. https://doi.org/10.3389/fnhum.2016.00601

Benjamin, R. (2019). *Race after technology: Abolitionist tools for the new Jim code*. Polity.

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*(2), 103–124. https://doi.org/10.1207/S15327965PLI1302_01

Castaneda, L. M., Bindman, S. W., Cechony, A., & Sidhu, M. (2018). The disconnect between real and virtually real worlds: The challenges of using VR with adolescents. *Presence (Cambridge, Mass.)*, *26*(4), 453–453. https://doi.org/10.1162/PRES_a_00310

Cellini, N., Canale, N., Mioni, G., & Costa, S. (2020). Changes in sleep pattern, sense of time and digital media use during COVID-19 lockdown in Italy. *Journal of Sleep Research*, *29*(4), Article e13074. https://doi.org/10.1111/jsr.13074

Centers for Disease Control and Prevention. (2021). February 22). *Child development*. U.S. Department of Health & Human Services. https://www.cdc.gov/ncbddd/childdevelopment/positiveparenting/index.html

Chen, Y., Garcia-Vergara, S., & Howard, A. M. (2015). Effect of a home-based virtual reality intervention for children with cerebral palsy using super pop VR evaluation metrics: A feasibility study. *Rehabilitation Research and Practice*, *2015*, Article 812348. https://doi.org/10.1155/2015/812348

Clark, L. S. (2011). Parental mediation theory for the digital age. *Communication Theory*, *21*(4), 323–343. https://doi.org/10.1111/j.1468-2885.2011.01391.x

Criado Perez, C. (2019). *Invisible women: Exposing data bias in a world designed for men*. Random House.

De Leo, G., Diggs, L. A., Radici, E., & Mastaglio, T. W. (2014). Measuring sense of presence and user characteristics to predict effective training in an online simulated virtual environment. *Simulation in Healthcare*, *9*(1), 1–6. https://doi.org/10.1097/SIH.0b013e3182a99dd9

Dede, C., Salzman, M., Loftin, R. B., & Ash, K. (1997). *Using virtual reality technology to convey abstract scientific concepts. Learning the sciences of the 21st Century: Research, design, and implementing advanced technology learning environments*. Lawrence Erlbaum.

Drouin, M., McDaniel, B. T., Pater, J., & Toscos, T. (2020). How parents and their children used social media and technology at the beginning of the COVID-19 pandemic and associations with anxiety. *Cyberpsychology, Behavior and Social Networking*, *23*(11), 727–736. https://doi.org/10.1089/cyber.2020.0284

Farr, W. J., Green, D., Bremner, S., Male, I., Gage, H., Bailey, S., Speller, S., Colville, V., Jackson, M., Memon, A., & Morris, C. (2021). Feasibility of a randomised controlled trial to evaluate home-based virtual reality therapy in children with cerebral palsy. *Disability and Rehabilitation*, *43*(1), 85–97. https://doi.org/10.1080/09638288.2019.1618400

Felnhofer, A., Kothgassner, O. D., Beutl, L., Hlavacs, H., & Kryspin-Exner, I. (2012). *Is virtual reality made for men only? Exploring gender differences in the sense of presence* [Conference session]. Proceedings of the International Society on Presence Research, Philadelphia, United States.

Golomb, M. R., McDonald, B. C., Warden, S. J., Yonkman, J., Saykin, A. J., Shirley, B., Huber, M., Rabin, B., Abdelbaky, M., Nwosu, M. E., Barkat-Masih, M., & Burdea, G. C. (2010). In-home virtual reality videogame telerehabilitation in adolescents with hemiplegic cerebral palsy. *Archives of Physical Medicine and Rehabilitation*, *91*(1), 1–8 https://doi.org/10.1016/j.apmr.2009.08.153

Hakkinen, J., Vuori, T., & Paakka, M. (2002). *Postural stability and sickness symptoms after HMD use*. In IEEE International Conference on Systems, Man and Cybernetics (Vol. 1, pp. 147–152). IEEE.

Harrington, C. M., Kavanagh, D. O., Wright Ballester, G., Wright Ballester, A., Dicker, P., Traynor, O., Hill, A., & Tierney, S. (2018). 360 Operative videos: A randomised cross-over study evaluating attentiveness and information retention. *Journal of Surgical Education*, *75*(4), 993–1000. https://doi.org/10.1016/j.jsurg.2017.10.010

He, J., & Freeman, L. A. (2019). Are men more technology-oriented than women? The role of gender on the development of general computer self-efficacy of college students. *Journal of Information Systems Education*, *21*(2), 7.

Herrera, F., Bailenson, J. N., Weisz, E., Ogle, E. & Zaki J. (2018) Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. *PLOS ONE*, *13*(10), Article e0204494. https://doi.org/10.1371/journal.pone.0204494

Hofferth, S. L. (2010). Home media and children's achievement and behavior. *Child Development*, *81*(5), 1598–1619. https://doi.org/10.1111/j.1467-8624.2010.01494.x

Hoque, M. E. (2016). Three domains of learning: Cognitive, affective and psychomotor. *The Journal of EFL Education and Research*, *2*(2), 45–52.

Huber, B., Highfield, K., & Kaufman, J. (2018). Detailing the digital experience: Parent reports of children's media use in the home learning environment. *British Journal of Educational Technology*, *49*(5), 821–833. https://doi.org/10.1111/bjet.12667

Huffman, A. H., Whetten, J., & Huffman, W. H. (2013). Using technology in higher education: The influence of gender roles on technology self-efficacy. *Computers in Human Behavior*, *29*(4), 1779–1786. https://doi.org/10.1016/j.chb.2013.02.012

Jun, H., Miller, M. R., Herrera, F., Reeves, B., & Bailenson, J. N. (2020). Stimulus sampling with 360-videos: Examining head movements, arousal, presence, simulator sickness, and preference on a large sample of participants and videos. *IEEE Transactions on Affective Computing*, 1 https://doi.org/10.1109/TAFFC.2020.3004617

Kalyanaraman, S. S., Penn, D. L., Ivory, J. D., & Judge, A. (2010). The virtual doppelganger: Effects of a virtual reality simulator on perceptions of schizophrenia. *Journal of Nervous and Mental Disease*, *198*(6), 437–443. https://doi.org/10.1097/NMD.0b013e3181e07d66

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology*, *3*(3), 203–220. https://doi.org/10.1207/s15327108ijap0303_3

Lee, S. J., Bartolic, S., & Vandewater, E. A. (2009). Predicting children's media use in the USA: Differences in cross-sectional and longitudinal analysis. *British Journal of Developmental Psychology*, *27*(1), 123–143. https://doi.org/10.1348/026151008X401336

Liebeskind, K. G., Piotrowski, J. T., Lapierre, M. A., & Linebarger, D. L. (2014). The home literacy environment: Exploring how media and parent–child interactions are associated with children's language production. *Journal of Early Childhood Literacy*, *14*(4), 482–509. https://doi.org/10.1177/1468798413512850

Livingstone, S., & Helsper, E. J. (2008). Parental mediation of children's Internet use. *Journal of Broadcasting & Electronic Media*, *52*(4), 581–599. https://doi.org/10.1080/08838150802437396

Mado, M., Herrera, F., Nowak, K., & Bailenson, J. (2021). Effect of virtual reality perspective-taking on related and unrelated contexts. *Cyberpsychology, Behavior and Social Networking*, *24*(12), 839–845. https://doi.org/10.1089/cyber.2020.0802

Makransky, G., Andreasen, N. K., Baceviciute, S., & Mayer, R. E. (2020). Immersive virtual reality increases liking but not learning with a science simulation and generative learning strategies promote learning in immersive Virtual Reality. *Journal of Educational Psychology*. Advance online publication. https://doi.org/10.1037/edu0000473

Makransky, G., Borre-Gude, S., & Mayer, R. E. (2019). Motivational and cognitive benefits of training in immersive virtual reality based on multiple assessments. *Journal of Computer Assisted Learning*, *35*(6), 691–707. https://doi.org/10.1111/jcal.12375

Martingano, A. J., Herrera, F., & Konrath, S. (2021). Virtual reality improves emotional but not cognitive empathy: a meta-analysis. *Technology, Mind, and Behavior*, *2*(1), https://doi.org/10.1037/tmb0000034

Mayer, R. E. (2017). Using multimedia for e-learning. *Journal of Computer Assisted Learning*, *33*(5), 403–423. https://doi.org/10.1111/jcal.12197

Mendoza, K. (2009). Surveying parental mediation: Connections, challenges and questions for media literacy. *The Journal of Media Literacy Education*, *1*, 28–41.

Moreno, R., & Mayer, R. E. (2002). Learning science in virtual reality multimedia environments: Role of methods and media. *Journal of Educational Psychology*, *94*(3), 598–610. https://doi.org/10.1037/0022-0663.94.3.598

Munafo, J., Diedrick, M., & Stoffregen, T. A. (2017). The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Experimental Brain Research*, *235*(3), 889–901. https://doi.org/10.1007/s00221-016-4846-7

Nikken, P., & Jansz, J. (2006). Parental mediation of children's videogame playing: A comparison of the reports by parents and children. *Learning, Media and Technology*, *31*(2), 181–202. https://doi.org/10.1080/17439880600756803

Nikken, P., & Schols, M. (2015). How and why parents guide the media use of young children. *Journal of Child and Family Studies*, *24*(11), 3423–3435. https://doi.org/10.1007/s10826-015-0144-4

O'Dea, R. E., Lagisz, M., Jennions, M. D., & Nakagawa, S. (2018). Gender differences in individual variation in academic grades fail to fit expected patterns for STEM. *Nature Communications*, *9*(1), Article 3777. https://doi.org/10.1038/s41467-018-06292-0

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology*, *110*(6), 785–797. https://doi.org/10.1037/edu0000241

Peck, T. C., Sockol, L. E., & Hancock, S. M. (2020). Mind the gap: The underrepresentation of female participants and authors in virtual reality research. *IEEE Transactions on Visualization and Computer Graphics*, *26*(5), 1945–1954. https://doi.org/10.1109/TVCG.2020.2973498

Queiroz, A. C. M., Nascimento, A. M., Tori, R., & da Silva Leme, M. I. (2018). Using HMD-based immersive virtual environments in primary/K-12 education. In D. Beck, C. Allison, L. Morgado, J. Pirker, A. Peña-Rios, T. Ogle, J. Richter & C. Gütl (Eds.), *Immersive learning research network. iLRN 2018. Communications in computer and information science* (Vol. 840). Springer. https://doi.org/10.1007/978-3-319-93596-6_11

Rideout, V. (2014). January). Learning at home: Families' educational media use in America. *A report of the Families and Media Project*. The Joan Ganz Cooney Center at Sesame Workshop.

Rupp, M. A., Odette, K. L., Kozachuk, J., Michaelis, J. R., Smither, J. A., & McConnell, D. S. (2019). Investigating learning outcomes and subjective experiences in 360-degree videos. *Computers and Education*, *128*, 256–268. https://doi.org/10.1016/j.compedu.2018.09.015

Segovia, K. Y., & Bailenson, J. N. (2009). Virtually true: Children's acquisition of false memories in virtual reality. *Media Psychology*, *12*(4), 371–393. https://doi.org/10.1080/15213260903287267

Shaphiro, S., & Wilk, M. (1965). An analysis of variance test for normality. *Biometrika*, *52*(3), 591–611. https://doi.org/10.1093/biomet/52.3-4.591

Sharar, S. R., Carrougher, G. J., Nakamura, D., Hoffman, H. G., Blough, D. K., & Patterson, D. R. (2007). Factors influencing the efficacy of virtual reality distraction analgesia during postburn physical therapy: Preliminary results from 3 ongoing studies. *Archives of Physical Medicine and Rehabilitation*, *88*(12), S43–S49. https://doi.org/10.1016/j.apmr.2007.09.004

Stanney, K., Fidopiastis, C., & Foster, L. (2020). Virtual reality is sexist: But it does not have to be. *Frontiers in Robotics and AI*, *7*, Article 4. https://doi.org/10.3389/frobt.2020.00004

Stanney, K. M., Hale, K. S., Nahmens, I., & Kennedy, R. S. (2003). What to expect from immersive virtual environment exposure: Influences of gender, body mass index, and past experience. *Human Factors*, *45*(3), 504–520. https://doi.org/10.1518/hfes.45.3.504.27254

Tranquada, S., & Correia, N. (2018). *The perseverance of gender stereotype*. In Proceedings of the 32nd International BCS Human Computer Interaction Conference 32 (pp. 1–6).

Ullman, E. (1997). *Close to the machine: Technophilia and its discontents*. City Lights Books.

UNESCO. (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)*. United Nations Educational, Scientific, and Cultural Organization. https://unesdoc.unesco.org/images/0025/002534/253479E.pdf

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin*, *140*(4), 1174–1204. https://doi.org/10.1037/a0036620

Walshe, N., & Driver, P. (2019). Developing reflective trainee teacher practice with 360-degree video. *Teaching and Teacher Education*, *78*, 97–105. https://doi.org/10.1016/j.tate.2018.11.009

W.H.O. (2012). *Gender and health*. https://www.who.int/health-topics/gender#tab=tab_1

Wiener, A. (2020). *Uncanny valley: A memoir*. MCD.

Woodard, E. H., & Gridina, N. (2000). *Media in the home*. Annenburg Public Policy Center of the University of Pennsylvania.

(*Appendix follows*)

Appendix

Database of VR Applications

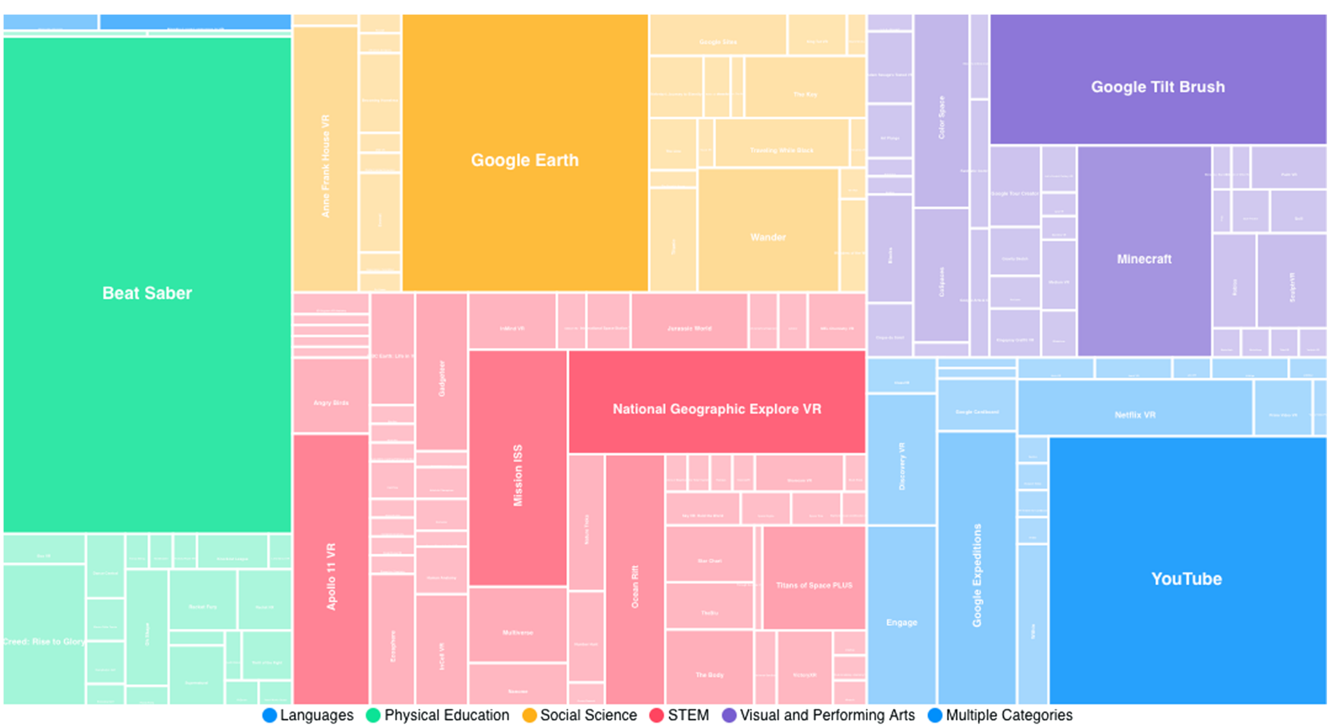
In order to address the challenge related to the accessibility of educational VR materials, and thereby support parents and educators with discovering content, this study provides an online database of 169 educational VR applications that were mentioned in the data collected at https://www.stanfordvr.com/edvrapps/. Each of these applications was mentioned in the surveys or interviews by one or more of the 308 participants. Two researchers scrutinized each of the 439 VR apps that were mentioned by the participants and selected 169 applications that were deemed to have educational value (as opposed to merely entertainment). The researchers then coded the educational VR apps for the deductively and inductively derived school subjects they relate to.

Deductively, as there are no national U.S.A.-based standards for school subjects, the researchers followed the California High School Requirements, which listed Science (Biology, Chemistry, and Physics), Social Science (History, Geography, Civics, Economics, and Culture), Mathematics, English, Foreign Language, Physical Education, Visual, and Performing Arts. By means of inductive reasoning, three categories were added: Environmental Science, Astronomy, and Engineering. The subcategory Anatomy was created in Biology. Civics, Economics, and Cultural Studies were combined into Civics. Some apps provided content for several school subjects and were categorized as Educational Package or Media Player. The Educational Package category consists of bundled sets of various types of VR experiences sold together and not available for individual purchase (e.g., Labster). The Media Player category refers to apps that allow users to stream various educational content videos. Figure 4 shows the apps colored by educational category and sized according to the number of individual households that mentioned each app. Both Media Player and Educational package categories are reflected as "Multiple" in Interactive Figure A1.

The online database of 169 educational VR apps includes the name of the app, a short description, the number of individual households who mentioned using the app, and the school subject categories that apply to each app. The findings show that 55% of the apps were mentioned by only one or two households. In addition, out of 169 apps, only six are mentioned by more than 10% of the households. These are Beat Saber (55%), Youtube 360 (29%), Google Earth (26%), Google Tilt Brush (17%), National Geographic Explore VR (12%), and Minecraft (11%). The findings also indicate that a large proportion of apps cater to Virtual and Performing Arts, Biology, and Physical Education, while the school subjects Mathematics, English, and Foreign Languages are underrepresented in VR content (Figure A2).

Figure A1

Screenshot of the Interactive Figure of Educational Apps Reported by Parents as Used by Their Children

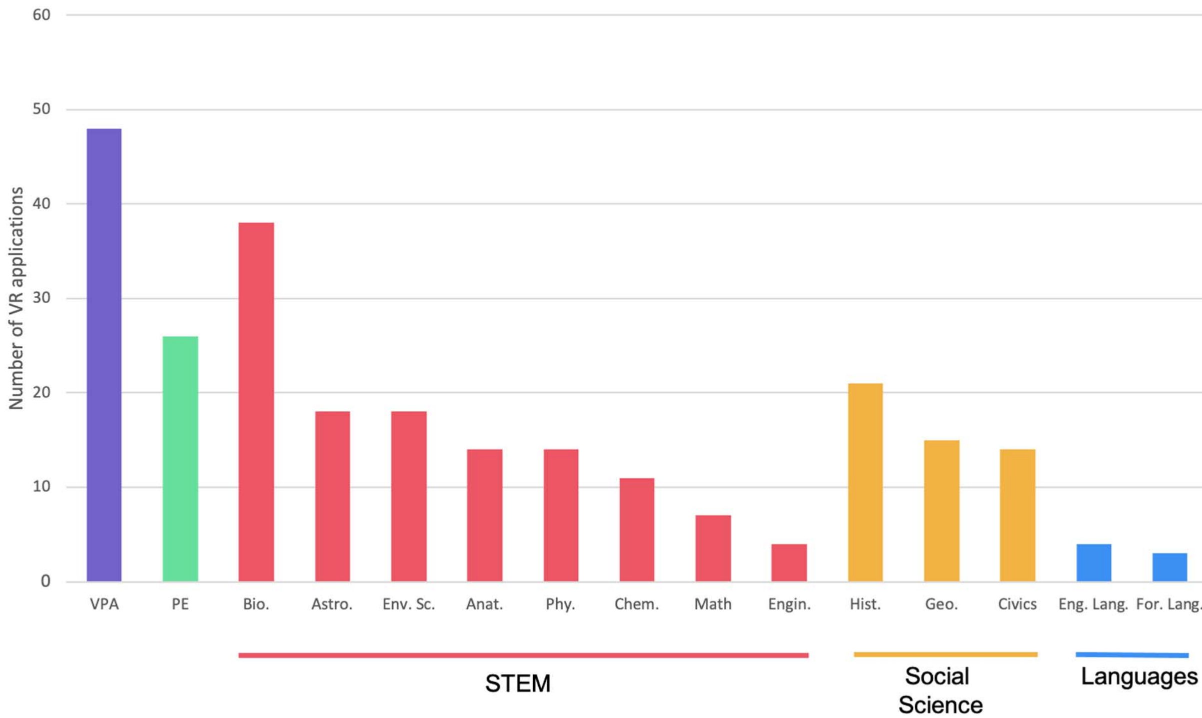


Note. Hover over the boxes to read all the apps and see the number of individual households that mentioned using this app, the number of which is also reflected in the size of the boxes. STEM = Social Science and Languages; VR = virtual reality. Available at https://www.stanfordvr.com/edvrapps/.

(*Appendix continues*)

Figure A2

Number of Apps Relating to Each School Subject



Note. The school subjects are clustered by school subject areas: VR = virtual reality; STEM = Social Science and Languages; VPA = Visual and Performing Arts; PE = Physical Education; Bio. = Biology; Astro. = Astronomy; Env. Sc. = Environmental Science; Anat. = Anatomy; Phy. = Physics; Chem. = Chemistry; Engin. = Engineering and Creation; Hist. = History; Geo. = Geography; Eng. Lang = English Language; For. Lang. = Foreign Languages.

Received June 23, 2021
Revision received December 9, 2021
Accepted December 11, 2021 ■