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INTELLIGENCE BRIEFING

Extended Reality technologies
and child sexual exploitation and abuse

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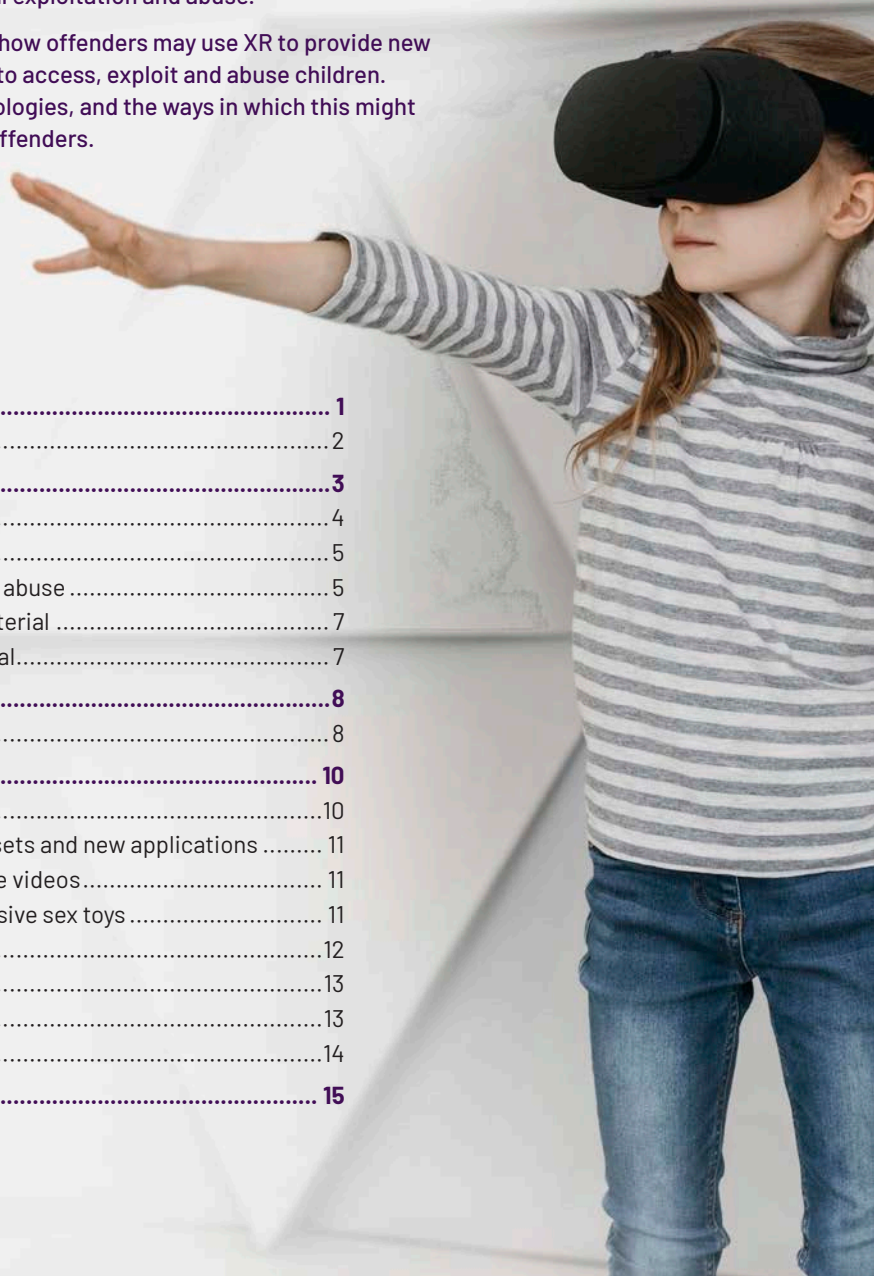
Introduction

This briefing examines the impact of increasing adoption of immersive 'eXtended Reality' (XR) technologies on child sexual exploitation and abuse.

Drawing on multidisciplinary research, we explore how offenders may use XR to provide new opportunities and enhance existing opportunities to access, exploit and abuse children. We also examine the future trajectory of XR technologies, and the ways in which this might influence their attractiveness to and adoption by offenders.

We conclude with some recommendations for reducing harm to children in XR contexts.



Contents

About this briefing

This briefing was developed by Professor Emma Barrett OBE, CPsychol, Professor of Psychology, Security and Trust, Department of Criminology, The University of Manchester.

It is a shorter and updated version of a longer research report which was commissioned and funded by GCHQ 2020-22, to inform their understanding of the future technologies that may be used in abuse and exploitation of children.

However, the views expressed are those of the authors (Professor Emma Barrett, Professor Stephen Pettifer, Dr James Marsh, Dr Sandra Flynn, Dr Polly Turner and Kathryn Hill).

What is XR?

'eXtended Reality' (XR) is an umbrella term for a range of technologies that includes:

Virtual Reality (VR), where the user engages in an artificially mediated, immersive experience, usually simulating a 3D world with sensory input from the physical world and displayed by a stereoscopic headset that blocks out the user's surroundings.

Augmented Reality (AR), where a user views digital content overlaid on the physical world, for instance, via a smartphone app or through a specially designed headset.

Mixed Reality (MR), in which a user experiences a believable synthetically generated 3D environment blended with the physical world around the user. Synthetic objects are not just overlaid on the screen in two dimensions but oriented and located so that they appear to be part of the physical environment and move accordingly as the viewpoint changes.

XR technologies and content have been around in one form or another for several decades. However, the last few years have seen a rapid acceleration in interest and availability in workplaces and consumer leisure sectors, with many established tech companies having invested heavily in XR .

Meta's announcement in 2021 that it was investing in the 'metaverse', and its launch of easy-to-use, affordable, leisure-focused VR headsets and applications, played an important part in increasing consumer awareness and adoption of VR. The uses of and potential for XR technologies are cross-sector and a range of XR experiences available to consumers is likely to remain in the coming years. However, the XR industry is still in a state of flux and as of early 2023 it is unclear whether it will continue to expand or whether recent cuts in XR investment by major companies, and lower than anticipated interest in new headsets, signal a levelling off or even decline in interest in such technologies.

Users can interact with XR environments in a variety of ways, and technologies vary in sophistication, and therefore cost and accessibility.

For instance, AR can involve overlaying computer-generated imagery on a view of the real world inside a headset using mirrors, prisms, or translucent screens; combining 3D imagery with a video feed of the physical world within a headset; or simply using the video camera on a mobile phone or tablet computer and combining the video feed with synthetically generated 3D objects before displaying it.

Until the late 2010s, good quality VR could only be experienced with a headset connected to a high-performance PC, but more recent headsets can be used as standalone (Wi-Fi-connected) devices. This provides more freedom for the user to move about a physical space, for as long as the battery lasts.

Sensory stimulation is central to a VR experience. In theory, a VR experience has the potential to stimulate all five of a user's senses. Sight and sound are most common. However, haptic devices are becoming available to both general consumers and specialist users. These create tactile experiences by simulating movement, resistance, or other sensation (e.g., vibration, force feedback) against a user's skin in response to user actions and interactions (sometimes known as 'kinaesthetic communication'). Haptic devices may be handheld (e.g., built into the controllers), wearable (e.g., gloves, shoes, suits), or inserted (e.g., sex toys)[1].

The inclusion of virtual smells and tastes is at an early stage, although in late 2022 OVR Technology demonstrated "wearable scent technology" (a cartridge-based device that apparently connects to a VR headset via Bluetooth).

The development of haptics has generated interest in technology innovation communities, in part stimulated by start-ups seeking investment. Unbiased predictions for likely uptake are hard to find, and as with XR more generally, it is too early to say whether the integration and use of haptics will become more commonplace.

1 - Yin, J., Hinchet, R., Shea, H. and Majidi, C., 2021. Wearable soft technologies for haptic sensing and feedback. Advanced Functional Materials, 31(39), p.2007428.

Ley, M. and Rambukkana, N., 2021. Touching at a distance: digital intimacies, haptic platforms, and the ethics of consent. Science and Engineering Ethics, 27, pp.1-17.

Applications of XR

Experiences available through XR have proliferated. Although still niche, work-related applications have become more available, including for holding VR gatherings in simulated offices, meeting rooms or conference venues, and AR and MR applications used to visualise and interact with manufacturing processes. Our focus here, however, is the expanding number of applications for the XR consumer market.

In AR, cheap mobile device applications have increased in availability, driven by the increasing ease of creating AR applications: standard application programming interfaces (APIs) in Apple's iOS and Android perform the complicated video analysis on behalf of the application.

Consumer applications include interior design and fashion applications that allow customers to see what a room would look like painted in a different paint colour, or what different clothes or hairstyles might look like on a digital representation of themselves. AR mapping applications typically display location-based information overlaid on the physical world viewed through the screen of a smartphone. AR games are also common, such as Pokémon Go, in which players use mobile device GPS location to locate, capture, battle and train fantasy characters that appear when the 'real world' is viewed through a mobile device screen.

The cost of entry to VR has become affordable for many consumers, with earlier versions of headsets, (such as Meta's Quest, Sony's PlayStation VR, and Pico VR), affordable for increasing numbers of consumers. However, in 2022-23, new and upgraded headsets are retailing at higher costs. The impact on uptake of VR remains to be seen.

The cost of VR applications is in the same range as more traditional PC-based games and applications. VR applications include interactive experiences, such as exploring virtual social worlds, engaging in single- and multi-player gaming, and fitness activities (for instance, 'boxercise' within a VR gym or playing table tennis with another user).

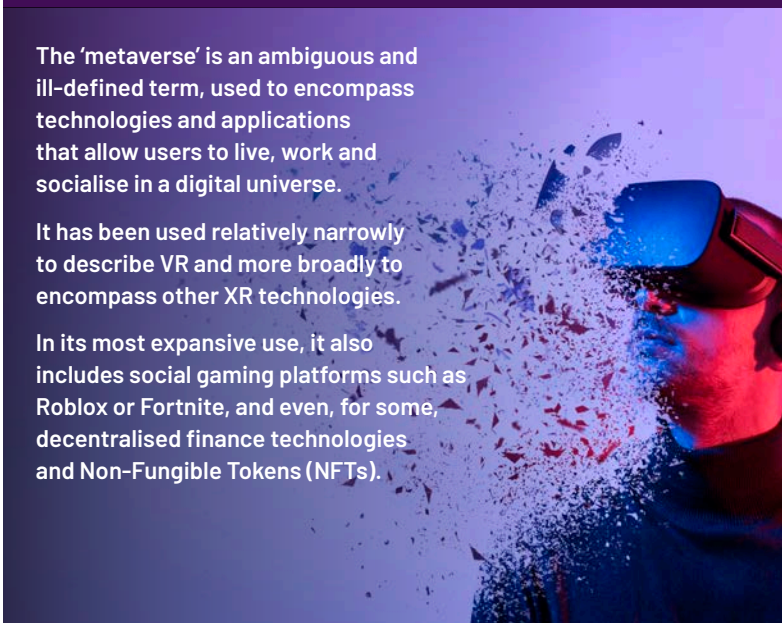
Other applications let users explore an environment, sometimes interacting with it, for instance, 'walking through' a museum, perhaps clicking on 'objects' to reveal additional information or trigger audio-visual content. Finally, users can watch film and video, and attend performances and sports matches in virtual spaces, sometimes recorded, sometimes live.

In this briefing, we use the term XR rather than 'metaverse'.

The 'metaverse' is an ambiguous and ill-defined term, used to encompass technologies and applications that allow users to live, work and socialise in a digital universe.

It has been used relatively narrowly to describe VR and more broadly to encompass other XR technologies.

In its most expansive use, it also includes social gaming platforms such as Roblox or Fortnite, and even, for some, decentralised finance technologies and Non-Fungible Tokens (NFTs).



Many VR applications rely on other characters being depicted in the environment interacting with the user. In multi-player games or social VR applications these characters include 'avatars' embodying fellow human participants, but may also include synthetic, computer-controlled characters. Emotional engagement and connection is fostered through a sense of 'co-presence': the degree to which such characters are credible to the user, for instance, whether the activities the characters undertake are believable, the degree to which they demonstrate intention and intelligence, and the expressiveness of the animation.

Accessing and creating content

App stores

Most consumer content is accessed via app stores controlled by platform providers. What content is available on any given platform depends on barriers to publication (i.e., what the app store allows). The lack of interoperability between platforms may also hamper developers and reduce availability: the development effort required to make different versions of an app for different platforms may not make economic sense, depending on the popularity of the platform.

Consumer AR content for mobile phones is widely available in app stores like Google Play and the Apple App Store (industrial and workplace AR applications including those for more sophisticated AR viewers like Microsoft Hololens may be bespoke developments for specific customers or sectors). These stores have content rules that are designed to keep out illegal and harmful content. Android phones do not require the use of the Google Play store, with other stores being available such as from Amazon and the opensource F-Droid repository, along with supporting manually installed applications.

VR content is available via several different platforms. Some software platforms are entirely controlled by a single company, such as Sony's PlayStation VR platform. As with AR content, to get published, applications must meet requirements for acceptable content and pass a review.

Valve's Steam Store, which sells games for PC-based VR, on the other hand, states: "We've decided that the right approach is to allow everything onto the Steam Store, except for things that we decide are illegal, or straight up trolling". Steam features many sexually explicit VR games.

Meta has its own curated store which is built into its VR platform. It has strict content guidelines but varying quality guidelines according to device. The Quest operating system is a modified version of Android and supports installing software from outside of the Meta store by plugging the headset into a desktop computer with a USB cable, a process commonly referred to as 'sideloading'. Sideloading requires the owner of the device to enable a development mode on the headset which in turn requires their identity to be verified. This has led to alternative stores, such as Sidequest and ImagineVR. Sidequest allows developers to publish experimental content, works in progress, and less polished games. ImagineVR has an 'over 18' section that is dominated by sexually explicit Japanese games.

Content creation

Creating XR digital environments is becoming easier, no longer requiring particularly sophisticated equipment or expertise. Capturing video of a physical scene, for instance, is straightforward using increasingly affordable 360-degree cameras.

When it comes to developing interactive and animated XR content, online courses are available to take hobby programmers and filmmakers through the basics to more advanced XR skills. AR content can be created using easily accessible and often free software development kits like Google ARCore, Apple ARKit, Spark (from Meta), and Snap Lens Studio. For VR content, Unity and Unreal are popular game engines for independent developers. Both are free for developers to use, until and unless they start earning revenue.

The evidence base

At time of writing (late 2022), we could find no works in the academic peer-reviewed literature that examine the use of XR in child abuse and exploitation specifically, although a growing number of articles highlight some challenges to child safety more broadly.

However, academics and scholarly organisations have published reports specifically on child abuse in XR, and child protection civil society organisations have also produced reports and articles.

Several journalists have written about child protection and XR technologies, with varying degrees of detail and sophistication. We are aware of research projects recently underway to clarify and develop understanding of child safety in XR, however, which may yield valuable future findings.

For instance, a project at the University of Maryland (US) seeks[1] to explore "teenagers' experiences and offenders' digital pathways that lead to online" child sexual exploitation. The University of Glasgow (UK) 'Facilitating Parental Insight and Moderation for Social VR' project will examine how social VR experience can be made safer for younger users. We have provided details of recommended reading in the Appendix.

1 – Deldari, E., Freed, D. and Yao, Y., 2022. Supporting A Safe and Healthy Immersive Environment for Teenagers. CHI EA '22, Proceedings of the 1st Workshop on Novel Challenges of Safety, Security and Privacy in Extended Reality, April 29-May 5, 2022, New Orleans, LA, USA

XR and the adult industry

The adult industry has traditionally been an early, prolific adopter and innovator in new technologies, and its adoption of XR has followed the same pattern. Recent years have seen the development of immersive video, erotic games, sexually-oriented social spaces, and a burgeoning sex-tech industry, including teledildonics – connected haptic devices that enable multi-sensory sexual experiences[2]. These developments are legal in most jurisdictions, and have benefits, for example, enabling quasi-realistic sexual experiences for people who might otherwise lack sexual contact, and as an outlet for creativity and play.

Numerous VR adult sites offer pre-recorded VR and AR pornography[3]. Consumption may be asynchronous, with recordings viewed and shared using VR headsets or smartphone VR. Users can view and experience the content in 3D as if it were occurring in front of them in a somewhat realistic way. The level of production can be 'amateur' (e.g., recorded by anyone using body-worn devices such as GoPro cameras; known as 'gonzo pornography') which may be for private use or sharing online, right up to professional outputs from commercial pornography studios. They may feature animated characters, avatars, or 'real' people.

Live adult chat rooms that enable live-streamed sexual performances that can be influenced by customers ('camming') have been available in VR for some time. More recently, the integration of teledildonics and other haptic devices in VR camming allows participants to have 'at a distance' physical interactions with each other, creating an interactive physical sexual experience for customers and performers.

Some applications allow users to produce computer-generated sexualised images with which users can then interact in XR, with Virt-a-mate being the most notable.

2 – Evans, L., 2022. Virtual Reality Pornography: a Review of Health-Related Opportunities and Challenges. Current Sexual Health Reports, pp.1-10.

3 – Asci, A., Baltaci, K.E., Altan, M. and Gudeloglu, A., 2020. PS-4-5 Pornography in the era of virtual reality. The Journal of Sexual Medicine, 17(6), p.S133.

XR technologies and child sexual exploitation and abuse

The published evidence base for the use of XR in child sexual abuse online offending is limited . This is partly due to the recency of developments in the consumer adoption of XR technology (academic research takes time to catch up). However, this is also a challenging area for researchers, with practical, ethical, and legal difficulties in carrying out research on offenders and victims and, often, in conducting research with organisations countering child sexual abuse online. Nevertheless, it is possible to make some judgements about how XR could impact child sexual abuse online offending, based on our understanding of offenders and victims' in non-XR online contexts and of the features of XR technologies; on anecdotal reporting from non-governmental organisations and government agencies currently combatting child sexual abuse online; and on some media/trade reporting.

In this section we consider how XR technologies may influence opportunities for offenders to access victims, distribution of child sexual abuse material, abuse of real children via XR technologies, including live XR chat rooms, and simulated abuse of virtual representations of children.

Opportunities to access and groom children

Virtual reality

Consumer VR use offers the most obvious and straightforward way for offenders to access children via XR. There are currently no legal restrictions on children's use of VR although the terms of use for most VR headsets state that they are not to be used by young children (e.g., for Meta and Sony the age limits are under 13 or under 12 respectively). Despite this, children under these ages use VR, often with the knowledge of their caregivers or older children[4]. Many VR applications are single-user, and have potential educational benefits[5]. However, where young people access VR social spaces, there are opportunities for offenders to access children from 18 years and younger.

As VR interactions are between avatars, offenders can choose how to present themselves to a child. For instance, they can pretend to be another young person, or a female, to befriend and groom their victim. Alternatively, they could pose as an authority figure (e.g., a moderator or law enforcement officer) to threaten or coerce their victim.

Many social spaces in VR offer opportunities to create invite-only 'private' spaces, which can be used to interact with other users (just as private spaces can be created in many non-VR social media applications). Offenders could use these spaces to deepen their relationship with children without being overheard or seen, in the same way that offenders may encourage victims to switch from communicating on social media to private messaging applications.

Augmented Reality

AR technology offers more limited potential to access unknown children, and there is no published evidence that offenders are specifically using AR for this purpose. However, opportunities exist to exploit AR to contact and groom children:

- Social games like Pokemon Go, where users travel to real world locations to 'catch' virtual characters, could be used to attract victims to physical locations (there are anecdotal reports of muggers using such a tactic).
- The creation, use and sharing of playful and engaging AR content could be used to deepen relationships with potential victims. For instance, Snap Lens Studio has developed the facility for users to create Connected Lenses where users can "invite your friends to chat, play, and interact in real-time whether they're across the room or across the world".
- AR can also be used during video chat to conceal or change an offender's appearance. For instance, AR filters in social media that make users appear 'cute' (e.g., overlaying computer generated cat whiskers on a user's face) or obfuscate a face altogether (e.g., becoming a Lego character).
- The monetisation of some AR content as 'digital goods' (for instance, as announced by Snap in late 2022) raises the prospect of such goods being offered as gifts to children.

Unlike the exploitation of VR, use of AR technology in these ways is largely an evolution of common methods of using social media or gaming platforms to meet and groom children, rather than the creation of an entirely new space.

4 – As early as 2018, Common Sense Media reported that in a survey of parents with children under 18, 43% agreed that it is appropriate for children under 13 to use VR.
https://www.commonsensemedia.org/sites/default/files/research/report/csm_vr101_final_under5mb.pdf

5 – Mado, M. et al. (2022) 'Accessibility of Educational Virtual Reality for Children During the COVID-19 Pandemic', Technology, Mind, and Behavior, 3(1: Spring 2022). doi:10.1037/tmb0000066.

Opportunities to distribute child sexual abuse material

XR offers opportunities to share child sexual abuse material that has been generated on non-XR platforms as well as opportunities to generate and share new types of child sexual abuse material. This could occur through interactions in social spaces (e.g., chatrooms), via applications that facilitate user-generated images, and specially designed applications.

Sharing in social spaces

As noted above, many social spaces in VR offer opportunities to create invite-only 'private' spaces, which can be used to interact with other users and to share images and videos. These could be exploited to share child abuse material and other offence-relevant information between offenders.

Sharing through applications

XR could be used to share XR child sexual abuse material through specially designed applications. Mainstream AR and VR app stores have content rules that allow them to block and remove applications that deliver illegal or harmful content. However, stores with less restrictive rules – particularly those like ImagineVR which deliver adult content - may provide opportunities for distribution of applications that (knowingly or unknowingly) host child sexual abuse material.

Offenders may bypass app stores altogether and instead develop AR and VR applications that can be sideloaded (as described above).

Opportunities to create child sexual abuse material

Physical abuse of children

XR technologies provide new ways of producing child sexual abuse material, building on existing methods (like live webcam abuse) and extending tools and techniques that are already common in adult XR pornography.

Although academic research on VR pornography is still in its infancy, studies[6] have thus far indicated that users experience a greater sense of immersion and more arousal in VR pornography compared to two-dimensional forms of pornography. For both offenders and their victims, therefore, VR adds an additional intensity to abuse experienced online.

As noted earlier, creating XR content for asynchronous consumption is becoming easier with free software development kits and online training. Child sexual abuse offenders may take advantage of the same technology used in live adult VR chat rooms, to live-stream sexual abuse in VR or AR. This abuse could be influenced or directed by chat room visitors and could include the use of teledildonics and other haptic devices. Physical sexual abuse of children could thus be perpetrated by offenders who are not physically co-located with their victims.

Indecent synthetic images

As noted earlier, some adult applications allow users to create their own fantasy characters and then interact with them in XR, and anecdotal reporting suggests that such applications have been used to create sexualised representations of children. As technology develops, synthetic images will become increasingly realistic, and may incorporate 'deep faked' images of individual children.

Users may believe that creation of synthetic images is not harmful, but children can be indirectly harmed through the legitimisation and normalisation of interests in child sexual abuse material among offenders, which may encourage further offending. Children could also be groomed by using virtual depictions of child sexual abuse to desensitise potential victims to the concept of sex between adults and children.

6 – Evans, L. Virtual Reality Pornography: a Review of Health-Related Opportunities and Challenges. Curr Sex Health Rep (2022). https://doi.org/10.1007/s11930-022-00352-9

Elsey, J.W., van Andel, K., Kater, R.B., Reints, I.M. and Spiering, M., 2019. The impact of virtual reality versus 2D pornography on sexual arousal and presence. Computers in Human Behavior, 97, pp.35-43.

Simon, S.C. and Greitemeyer, T., 2019. The impact of immersion on the perception of pornography: A virtual reality study. Computers in Human Behavior, 93, pp.141-148.

Key challenges and opportunities

Potential risks to children in AR and VR are different. In AR, the risks stem from the creation of indecent images which can be overlaid onto an offender's physical environment to give the impression of having a child companion. These images may be of actual children or synthetic avatars and may normalise and legitimate interests in child sexual abuse material . The non-consensual exploitation of intimate images of real children is also a threat to a child's privacy and autonomy.

The risks in VR are more extensive and the potential for harm is more acute. As noted above, risks range from opportunities for grooming in social VR spaces through to new methods to create and stream abuse. In this section, therefore, we focus primarily on managing risks in VR.

Protecting children in VR

The primary methods for promoting child safety in online spaces are:

- preventing children accessing inappropriate content, via age restriction and parental controls
- allowing users to block or otherwise restrict interactions with other users
- content moderation, which may be human (manual) or automated
- advice and education for children and their caregivers about managing risks
- designing applications with children in mind ('safety by design').

Preventing access to harmful content

VR providers state in their terms of use that young children should not use their headsets. However, this does not prevent children using headsets registered to other family members or friends. Regular users of VR therefore include under-13s as well as young people between the age of 13 and 18. A wealth of anecdotal accounts and a small number of academic studies have documented engagement of young children in VR spaces, including concerning interactions with adults[7].

Age assurance in VR spaces is theoretically possible, given the huge amount of biometric data gathered by sensors in VR headsets. These could, for instance, establish if the headset is being used by someone who is not the registered user and who is likely to be a child, based on height, gait, voice pitch and so on. Such measures could be useful as part of a suite of methods to protect children but raise significant privacy concerns.

Currently, there is limited ability for parents and guardians to monitor or restrict their children's VR experiences, although some platforms have introduced parental control measures.

For instance, the parents and guardians of Meta Quest users have the ability to restrict access to some applications on headsets registered to over-13s. These controls are an important step forward, although they are relatively modest, do not apply to under-13s, and children can still use someone else's headset to access age-inappropriate applications.

Blocking and moderation

Many platforms and apps have user codes of conduct that set out what is allowed and what is unacceptable. Enforcing such codes requires mechanisms for content moderation and/or blocking of users. Platforms and apps have the power to remove and block users, but detecting that a user is engaged in unacceptable conduct can be difficult, as can ensuring that the user does not rejoin under a different identity.

In many applications, users can themselves block and report other users, but that can be time-consuming and difficult (depending on the platform or application's reporting processes), and dangerous behaviour is not always immediately obvious (in the case of grooming for example). Once a user has reported someone, they rarely get feedback on what action has been taken. And if a child is using someone else's headset, they may not want to draw attention to themselves by contacting the platform.

Proving that abusive or dangerous behaviour has occurred can also be problematic if users do not routinely record all of their interactions. Live VR interactions may otherwise leave little in the way of a meaningful lasting digital footprint[8].

7 – Maloney, D., Freeman, G. and Robb, A., 2020, November. A virtual space for all: Exploring children's experience in social Virtual Reality. In Proceedings of the Annual Symposium on Computer-Human Interaction in Play (pp. 472-483).

Centre for Countering Digital Hate (2022) Facebook's Metaverse

8 – A. Yarramreddy, P. Gromkowski and I. Baggili, "Forensic Analysis of Immersive Virtual Reality Social Applications: A Primary Account," 2018 IEEE Security and Privacy Workshops (SPW), San Francisco, CA, USA, 2018, pp. 186-196, doi: 10.1109/SPW.2018.00034.

Another approach is for social spaces to be 'policed' by moderators. For example, human moderation has been used in some social spaces (for instance, in the now-sunsetted AltSpaceVR) to prevent trolls disrupting meetings. However, it is impossible for all spaces to be moderated by a human, and anecdotal accounts suggest that even when moderators are present in spaces where children are at risk, action may not be taken.

For smaller companies with limited resources there is a strong incentive to devolve moderation to users along with encouraging the creation of worlds and other content. While giving a sense of ownership of the virtual environment to the users, a risk of this approach (taken by popular applications such as VR Chat, Bigscreen Cinema, and Second Life) is that hidden environments can be created, with access through invitation only, containing undesirable or illegal content.

Given the volume of interactions in VR spaces, automated moderation is an attractive option, but will be profoundly challenging. Automating moderation (e.g., by scanning for abusive language) is difficult enough in 'traditional' online spaces, but in VR spaces, an automated moderation system must also contend with ephemeral interactions and potentially offensive non-verbal behaviour (e.g., gestures, display of signs and slogans, virtual 'groping' of or simulated sexual activity by avatars). Differentiating acceptable from unacceptable interactions is context-dependent and also, to an extent, dependent on the users involved. For instance, how might an automated system differentiate sexualised interactions between avatars controlled by adults versus the same type of interactions between an adult-controlled and a child-controlled avatar, particularly if in either case the avatar's apparent age is unclear? Users of online communities may also develop their own language to evade detection of potentially prohibited topics of conversation[9].

Advice and education

Given that XR devices are inevitably going to prove interesting and accessible to young children within households, an important way of managing risks is through advice and education. Although awareness of safety concerns is growing, many children and their caregivers are unaware of the risks and how to manage them. More information about the potential hazards and the ways to avoid them (from blocking and reporting through to simply removing the headset) could empower children to deal with unwanted behaviour. Greater awareness of parental controls and why they might be necessary will help caregivers to support safe use.

Encouraging relatives and guardians to accompany their children within social VR (e.g., with their own headset, or by mirroring the child's view on a family television and watching together) may also be beneficial, allowing children to learn from trusted adults and older children how to manage their own experiences and avoid unwanted attention.

For children, XR should be considered alongside other online activities in digital citizenship lessons from early in their education.

Education can also benefit users of VR pornography, making them aware that producing and consuming indecent images of children in VR is as harmful as in other online and offline contexts, with equally severe legal consequences.

Safety by design

Rather than attempting to retro-fit safety measures in an already-released technology, a 'safety by design' approach reduces harm proactively by anticipating and addressing potential harms before the technology is released. In this context, it means considering how and when children may be less safe when using XR, how offenders may adapt and exploit features of the technology for criminal purposes, and designing in features to enhance safety and minimise harm.

9 – Jiang, J.A., 2020, April. Identifying and addressing design and policy challenges in online content moderation. In Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1-7).

Future scanning

XR technologies are evolving rapidly and becoming more common in education and the workplace, as well as at home. AR and VR are likely to be familiar parts of life for future generations.

This section summarises some likely trends in XR and speculates about how they might influence child sexual abuse online.

Consumer use of mobile Augmented Reality

Newer, more expensive mobile devices include dedicated hardware such as LiDAR as standard in phone cameras for determining distance to objects in a video . This can improve an AR experience; with accurate depth information, synthetic objects pass behind or appear to sit on more real-world objects than simply perfectly flat ground, tables, and desks.

AR on mobile and tablet devices is increasingly accessible and affordable to both offenders and victims. Such devices have the advantage also of familiarity, with a large proportion of the population having grown up with a smartphone or tablet. Balanced against this, however, as noted above, recent indications are that developer and consumer interest in AR may not be as strong as many predicted.

Exploiting legitimate AR-based games to attract children for abuse

Motivating game players to venture outside and explore the real environment has obvious health benefits but may also present risks. Children could be encouraged to explore unsafe areas such as building sites or alongside busy roads, by accident or design. In conventional online multiplayer games players often team up to defeat an enemy or solve or complete a quest. If this mechanism of gameplay is transferred to an outdoor AR game, this presents contact risks and opportunities for in-person grooming.

Using AR applications as part of child sexual abuse online fantasy

With improved depth information about a scene, characters could be made to explore a room, hide behind objects, sit on chairs, and seemingly interact realistically with physical objects. Offenders could exploit this by, for instance, creating scenarios in which they make a virtual representation of a child appear to sit next them (e.g., in their bedroom), viewed through a device screen. Alternatively, other people or items could be introduced in a scene involving an actual child to create a fantasy scenario.

Offenders could create applications that display virtual children in their own AR scene, including to create representations of abusive scenarios in their own home. Combining high-quality, freely available 3D models of children with faces from photographs it may be possible to make the child avatar look realistic, or even resemble a child known to the offender. With more advanced skills and 'deep-fake' approaches, faces could be animated in a plausible way to engage in dialogue 'inviting' abuse.

Dedicated software for this purpose is unlikely to be accepted into most curated mobile app stores. However, 'sideloaded' applications for Android and standalone PC software for mixed reality headsets could be distributed privately (e.g., on forums). The creation and distribution of such software in this manner will be difficult to police.

More uptake of self-contained, low-cost VR headsets and new applications

Workplace and consumer markets for VR headsets will continue to grow, with existing manufacturers like Meta and Sony launching new models and others entering the market. The anticipated launch of an Apple VR headset will likely bring VR to new audiences. Increasing use of VR in work settings (from manufacturing to healthcare to retail) will make the technologies increasingly familiar.

Learning new skills, overcoming inhibitions?

In high-risk workplaces, VR is already being used to train for situations which would present risk and ethical concerns in real life. Child sexual abuse offenders could plan and rehearse abusive behaviour in a virtual setting before re-enacting these actions against an actual child. This could encourage fantasy-driven offenders to overcome psychological barriers and fear of contact offending via engagement in rehearsal and exposure.

Availability of 3D cameras for recording immersive videos

Cameras capable of recording hemispherical and spherical videos for immersive video are becoming commonplace and affordable for the consumer. The development and increasing affordability of 180° or 360° cameras could hypothetically facilitate the live streaming of child sexual abuse to VR headsets. If and when mobile networks develop higher bandwidth and faster connectivity, streaming this material becomes more feasible, including allowing viewers to make real-time requests during live-streaming via microphones in VR headsets.

Growth of the market for teledildonics and immersive sex toys

The 'sex tech' industry will continue to grow in the coming years and technical obstacles to haptic devices being synced with a live XR performance are likely to be overcome. The adult VR industry will continue to innovate and we can expect continued development of immersive sex games that could include increasingly sophisticated teledildonic elements.

New ways to harm children

These developments in adult VR may be exploited by child sexual abuse online offenders. Devices could be used against children as part of abuse, potentially causing physical harm, and the increased believability of the experience may increase psychological harm. Live VR chat rooms featuring child abuse, potentially using teledildonics, may become available.

Reinforcing offending/risk behaviour

When imagery is synchronised with teledildonic/haptic devices, increasingly realistic tactile feedback can make it seem as though the user is touching the objects in the virtual scene which is likely to increase the believability. Repeated use with child sexual abuse online material can create a conditioning effect in the offender: a strong association between sexualised representations of children (visual stimulus) and the user's physical sexual response. Haptic feedback may intensify this association. For some offenders, this may lead to a desire for even more extreme material to facilitate the same level of sexual gratification.

Virtual Reality as prevention and response tools

Intervention and treatment of offenders

Virtual reality-based therapies could offer options for intervention, and treatment of offenders[10]. For instance:

- Empathy deficits are risk factors for sexual offending against children. Studies show that perspective-taking in VR can increase the level of empathy felt by users towards others which could be of value in offender treatment. For instance, one pilot in Spain has used VR as part of therapeutic intervention with intimate partner violence offenders. This raises the possibility of using VR to support offender rehabilitation, with the aim of increasing empathy for victims[11].
- Offender treatment may involve developing behavioural skills to cope when in a potentially risky situation (e.g., on encountering a child). One study[12] has indicated that VR could be used to train these coping skills.
- Assessing whether an offender can use these skills effectively is challenging, and often relies on an offender self-reporting that they were able to avoid risky behaviour. Preliminary studies suggest that VR could be used to monitor offenders' behaviour in virtual representations of risk situations (e.g., encountering a representation of a child during a 'walk'). This may be a more reliable method for assessing whether the offender is able to deploy coping skills effectively.

Empirical research on these potential uses of VR in offender rehabilitation and risk management is still at an early stage, with limited data to allow us to assess the value of VR approaches. Using VR in this context also raises a host of ethical (and potentially legal) issues[13]. Caution is warranted as this area develops.

Support for child abuse victims

Scholars have also suggested ways in which VR might be used as part of a therapeutic intervention with victims of abuse, particularly when treating anxiety, post-traumatic stress, and feelings of guilt, shame and depression. VR could also be used to enhance empathy, and therefore improve victim treatment, as part of the training of therapists and medical students.

As with the use of VR with offenders[14], the evidence for the use of VR in victim support and treatment is currently scant. More research and evaluation will be necessary before such interventions could be widely recommended.

10 – Fromberger, P., Jordan, K. and Müller, J.L., 2018. Virtual reality applications for diagnosis, risk assessment and therapy of child abusers. Behavioral sciences & the law, 36(2), pp.235-244.

11 – Barnes, N., Sanchez-Vives, M.V. and Johnston, T., 2022. On the practical use of immersive virtual reality for rehabilitation of intimate partner violence perpetrators in prison. Frontiers in psychology, p.597.

12 – Ticknor, B., 2018. Using virtual reality to treat offenders: An examination. International Journal of Criminal Justice Sciences, 13(2), pp.316-325.

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13 – Fromberger, P., Jordan, K. and Müller, J.L., 2018. Virtual reality applications for diagnosis, risk assessment and therapy of child abusers. Behavioral sciences & the law, 36(2), pp.235-244.

14 – Asadzadeh, A., Shahrokhi, H., Shalchi, B., Khamnian, Z. and Rezaei-Hachesu, P., 2022. Digital games and virtual reality applications in child abuse: A scoping review and conceptual framework. PLoS one, 17(11), p.e0276985.

Recommendations

As mentioned above, the XR industry is currently in a state of flux. Improvements in internet capabilities, development of better hardware, reduced costs, and the increased availability of high-quality immersive content may contribute to further growth in consumer adoption of XR. If, as industry commentators predict, use of XR tools will be commonplace in a few years, issues of child safety urgently need addressing now.

Regulation and enforcement

Several governments have or are considering new legislation to promote online safety. Such measures call on technology companies to do more to understand and address harm that could be caused or facilitated by their platforms. XR technologies are often not explicitly singled out but would be (or are intended to be) covered by most such proposals.

Even with legislation in place, enforcing laws in XR spaces will be challenging. A key concern is determining how abusive, dangerous and criminal behaviour in XR can be identified and tracked and, if necessary, offenders prosecuted, while still protecting freedom of expression and user privacy.

Recommendations:

- Regulators and lawmakers should ensure that XR harms are indeed covered by existing or new legislation and policy, and bear in mind that there are several types of risk to children, not just the widely publicised risk of grooming.
- When developing legislative and regulatory approaches, meaningful consultation across a wide range of stakeholders (from industry to civil society groups, and with users of all ages) is essential to ensure that proposed measures are effective and do not introduce unintended negative consequences for particular groups or communities.
- Investment in research and development is urgently required to support criminal investigation and prosecutions. This will require innovative thinking and new tools for digital investigation and digital forensics, and consideration of how evidence of child abuse activity in XR could be laid before a jury.

Platforms and content providers

As described above, technology companies and XR app developers should anticipate and mitigate safety issues before their products are rolled out.

This difficult task will be made easier if the international community develops (and industry adheres to) standards for 'safety by design' in XR.

A number of initiatives, led by NGOs, industry forums, and governments, now exist to support 'safety by design' through the development of international standards and advice and guidance. For instance:

- The XR Safety Initiative is working on a child safety framework that will identify ways of safeguarding children in XR.
- The IEEE Global Initiative on Ethics of Extended Reality brings together interdisciplinary, cross-sector groups to identify standards and practice recommendations to increase ethical and safe development of XR technologies.
- The Metaverse Standards Forum has an exploratory working group on Privacy, Cybersecurity & Identity, which will curate standards and policies from across jurisdictions. Their remit includes child safety.
- The Australian e-Safety Commissioner is at the forefront of developing and implementing regulation and guidance on safety by design, with several other governments close behind.

More effort (by governments, NGOs, academia, and technology companies) is required to bring the results of these initiatives together, translate them into action and to accelerate the development of safety measures such as parental controls and effective moderation.

Recommendations:

- From 2022 some VR providers started to introduce VR parental safety tools for teenagers and provide more explicit guidance on safe usage. This is a welcome development but will have the most impact if safety tools are adopted by all platform providers and guidance explained to parents prominently.
- Measures also need to be developed to protect pre-teens. This may be by developing robust age assurance measures, and/or by considering limited-access accounts for the youngest users.
- Platforms that host VR and XR app stores should only accept applications that meet safety standards, and should review these regularly to ensure they remain compliant.
- More attention should be paid to how users can protect themselves and be protected in XR via the application of moderation measures including automated and human moderation implemented by platforms, and user-controlled moderation and safety controls.
- 'Safety by design' approaches must address several types of risk to children, not just the widely publicised risk of grooming.

Education and guidance

Children and their caregivers need more education about the risks of XR technologies so they can make informed decisions about when and how to let children explore the rich opportunities of immersive virtual worlds safely.

It is also important that users of VR (particularly VR pornography) are aware that producing and consuming indecent images of children in VR is as harmful as in other online and offline contexts, with equally severe legal consequences.

Recommendations:

- More information about the potential hazards and the ways to avoid them (from blocking and reporting through to simply removing the headset) could empower children to deal with unwanted behaviour, and greater awareness of parental controls and why they might be necessary will help caregivers to support safe use.
- Encouraging relatives and guardians to accompany their children within social VR (or watching the child's VR experience together via the family television) may also be beneficial, allowing children to learn from trusted adults and older children how to manage their own experiences and avoid unwanted attention.
- For children, XR should be considered alongside other online activities in digital citizenship lessons from early in their education.
- Child protection organisations and campaigns that target potential users of child sexual abuse online (such as Stop It Now) should include XR in their awareness and prevention campaigns.

Appendix

Acronyms

XR: eXtended Reality
VR: Virtual Reality
AR: Augmented Reality
MR: Mixed Reality
NFTs: Non-Fungible Tokens
5G: 5th Generation
API: Application Programming Interface
GPS: Global Positioning System

Key definitions

NFT: Non-Fungible Token, a digital asset with a unique signature. An NFT can be bought and sold, with the record of ownership stored immutably on the blockchain. The token functions as a certificate of ownership.

Metaverse: An ill-defined term used to describe technologies and applications that allow users to live, work, and socialise in a digital universe. It can encompass VR, other XR technologies, social gaming platforms, and decentralised finance technologies and NFTs.

Extended Reality (XR): An umbrella term that includes virtual reality (VR), augmented reality (AR), and mixed reality (MR).

Augmented Reality (AR): Technology that superimposes digital information onto the physical world, displayed on a mobile device screen.

Mixed Reality (MR): A technology that combines elements of both AR and VR, with real and virtual objects coexisting in the same environment.

Virtual Reality (VR): Technology that creates a simulated environment that replaces or enhances the real-world.

Application Programming Interface (API): A set of guidelines and protocols for accessing a web-based software application or web tool.

App stores: Consumer AR & VR content is accessed via app stores controlled commonly by platform providers (e.g. Google Play, Apple App Store).

Child Sexual Abuse Material (CSAM): Illegal material depicting children in sexually explicit acts or poses.

Private spaces: Social spaces in VR that are invite-only and can be used to interact and share images/videos.

Mainstream AR/VR app stores: App stores from mainstream established technology companies.

Sideloading: Bypassing an official app store by installing an app or other software directly.

Live-streaming: Real-time streaming of a video feed.

Teledildonics: Sex toys that can be controlled remotely.

Synthetic images: Computer-generated images.

Deep faked images: Synthetic images manipulated using AI to to to seamlessly replace people or other parts of an image or video with 'fake' realistic content.

Grooming: The process of establishing an emotional connection with a child to prepare them for sexual abuse.

Blocking: The act of preventing a user from accessing certain parts or all of a platform or application.

Content moderation: The act of monitoring and regulating the type of content being generated and shared by users on a platform or application.

User codes of conduct: Rules set out by platforms or applications outlining what type of behavior is acceptable and what is not.

Automated moderation: Using technology and algorithms to monitor and regulate user-generated content on a platform or application.

Child sexual exploitation and abuse online: Abuse that is partly or entirely facilitated by technology, i.e. the Internet or other wireless communications.
This concept is also referred to as Online Child Sexual Exploitation and Abuse (OCSEA), and 'technology-facilitated' child sexual exploitation and abuse.

VR headset: A device that provides a virtual reality experience, via a head-mounted display and hand-held controllers.

VR spaces: Virtual environments in XR including those where users can interact with each other.

Human moderation: Monitoring and regulation of user-generated content by human moderators.

Child safety: Measures taken to ensure the protection and well-being of children.

Online safety: Measures taken to ensure the protection and well-being of users in online or virtual spaces.

Safety by design: Designing technology with safety and privacy in mind, considering potential risks and implementing measures to mitigate them.

Social VR: Virtual reality experiences that are social in nature, allowing multiple users to interact in virtual spaces.

Further Reading

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