Systematic Review

The Integration and Application of Extended Reality (XR) Technologies within the General Practice Primary Medical Care Setting: A Systematic Review

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Abstract: The COVID-19 pandemic instigated a paradigm shift in healthcare delivery with a rapid adoption of technology-enabled models of care, particularly within the general practice primary care setting. The emergence of the Metaverse and its associated technology mediums, specifically extended reality (XR) technology, presents a promising opportunity for further industry transformation. Therefore, the objective of this study was to explore the current application and utilisation of XR technologies within the general practice primary care setting to establish a baseline for tracking its evolution and integration. A systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) was conducted and registered with the international database of prospectively registered systematic reviews as PROSPERO-CRD42022339905. Eleven articles met the inclusion criteria and were quality appraised and included for review. All databases searched, inclusive of search terms, are supplied to enhance the transparency and reproducibility of the findings. All study interventions used virtual reality technology exclusively. The application of virtual reality within the primary care setting was grouped under three domains: (1) childhood vaccinations, (2) mental health, and (3) health promotion. There is immense potential for the future application of XR technologies within the general practice primary care setting. As technology evolves, healthcare practitioners, XR technology specialists, and researchers should collaborate to harness the full potential of implementing XR mediums.

1. Introduction

The COVID-19 pandemic has resulted in considerable disruption to the delivery of general practice primary healthcare services. Resources were diverted to address pandemic acuity, where pandemic policies significantly disrupted the delivery of healthcare services and necessitated the rapid adoption of technology-enabled service models of care [1,2]. Digital technologies, such as virtual telehealth care, were widely adopted and incentivised to facilitate remote patient and practitioner interactions, limiting person-to-person contact to reduce viral transmission [1,3,4]. After the pandemic, the ever-increasing prevalence of

non-communicable chronic disease, multimorbidity, aging populations, and the threat of future pandemics continue to challenge already strained global health services necessitating the continued transformation of traditional patient care services [3,5]. The continued evolution and integration of digital technologies, including the adoption of metaverse-enabled immersive extended reality (XR) mediums, have the potential to play a primary role in this transformation, further augmenting consumer and primary care physician interactions [3,4].

1.1. Extended Reality (XR)

Extended reality (XR) is an umbrella term used to describe a spectrum or continuum of "virtuality" technology mediums that are designed to alter our real-world view, including augmented reality (AR), virtual reality (VR), and mixed reality (MR) [3,6]. At one end of the spectrum is AR, referring to technology that augments the real-world view by overlaying or superimposing virtual objects onto it. This is typically achieved by using hardware such as smart glasses or smartphone/tablet devices, allowing users to see the digital elements while permitting full visibility of the user's real-world surroundings [3,7]. At the other end of the spectrum is VR, which significantly differs from AR and involves the use of head-mounted displays (HMDs) or headsets to block out the real world entirely. This allows users to be fully immersed in a computer-simulated three-dimensional (3D) environment, creating the physical and mental sensation of being in a virtual world [3,7]. In VR, users can interact with the virtual environment via the use of handheld controllers and receive direct sensory (images and sounds) feedback [8]. One fundamental aspect of VR is the concept of immersion [9]. Immersion refers to the extent to which users feel fully engaged and absorbed in a virtual environment, perceiving it as a substitute for their real-world surroundings. Currently, to achieve immersion, several different technological HMDs can be applied, ranging from simple devices (utilising mobile smartphones with compatible headsets) to more advanced systems, such as the HTC Vive and Oculus Rift (as displayed in Figure 1). Head-mounted displays are designed to substitute the user's real visual senses, allowing them to perceive and interact with the virtual environment as if it were real. Mixed reality sits in the middle of the spectrum between AR and VR, further blending the real and virtual worlds within a single display [2,6]. In MR, the real and virtual worlds blend seamlessly, creating an environment where physical objects behave as if they were part of the virtual world [6]. This integration is generally achieved through the use of HMDs to create experiences for purposeful interactions [4].
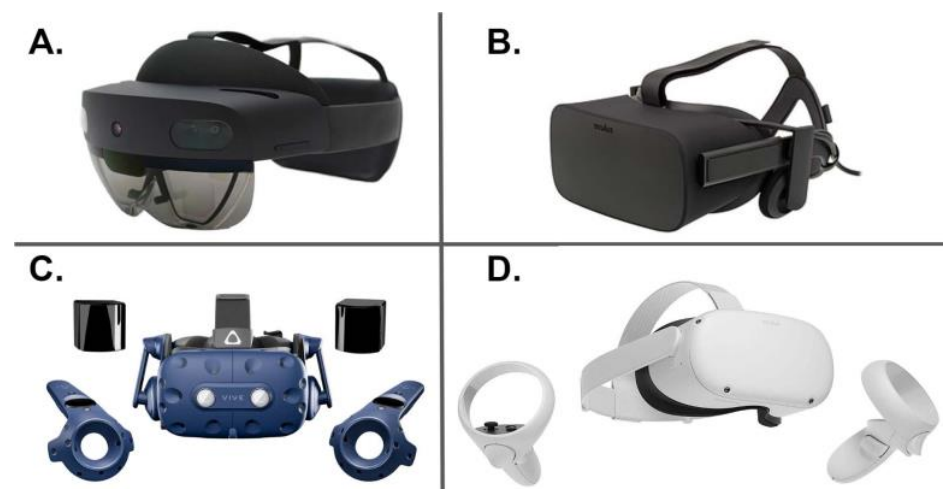

Figure 1. (**A**) Microsoft HoloLens 2. (**B**) Oculus Rift CV1. (**C**) HTC Vive. (**D**) Oculus Quest 2 [7].

1.2. The Metaverse

The metaverse is an evolving concept first described in the science fiction novel "Snow Crash" by Stephenson [10], who envisioned a virtual world that people could explore and interact with by use of digital avatars [11]. The metaverse essentially represents the extension of the virtuality continuum, representing the convergence of the real world into an immersive online and virtual interconnected environment that can be used for real-time interactions [12]. The metaverse at this time is further explained as an immersive internet computer simulation that can be accessed by using XR and other emerging accessory technologies [7,13]. The metaverse and its architecture are only limited by technological advancements, enabling the integration of artificial intelligence (AI), digital twin technology, telecommunications, the internet of medical things (IMOT), blockchain technology, wearables, and the integration of robotics [4]. The vision for the metaverse and its potential impact on healthcare as described by Musamih et al. [4] signifies an evolutionary shift wherein the physical world, involving healthcare personnel and patients, converges in a virtual realm known as the "metaverse". Within this digital environment, real-world participants can engage with healthcare services and systems using digital avatars that mimic real-world point-of-care interactions [4].

Building towards the vision of the metaverse, the therapeutic application of XR technology within medicine is increasing. A systematic review by Tang et al. (2021) [14] identified several applications of XR technology within the specialties of surgery (50 studies), urology (18 studies), neurology (13 studies), and medical education (66 studies for medical doctors and 56 studies for medical students). A narrative review by López-Ojeda and Hurley [15] further identified emerging applications of XR technologies within cardiology, dentistry, oncology, pain medicine, immunology, anaesthetics, dermatology, emergency medicine, family and internal medicine, obstetrics and gynaecology, ophthalmology, pathology, paediatrics, preventative medicine, and radiology. While XR has found its place in areas such as surgery and medical education, its therapeutic applications within the general practice primary care setting is an area for future development. General practitioners working in primary care settings are often the first point of contact for individuals seeking medical assistance, with the quality of care provided at this juncture significantly influencing health-seeking behaviours [16]. Given the reductions in face-to-face care due to the COVID-19 pandemic, understanding how XR technologies can be harnessed to improve diagnostics, treatment, and patient engagement within the primary care setting is pivotal to the continued provision of evidenced-based compassionate care [16]. Therefore, the aim of this systematic review was to investigate the utilisation and application of XR technologies within the general practice primary care setting to establish a baseline with which to track its evolution and application into the future. In the subsequent sections, we present our systematic approach towards identifying articles for inclusion and quality appraisal, culminating in a narrative synthesis of findings that contributes new insights to the evidence base.

2. Materials and Methods

This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [17]. An a priori review protocol and eligibility criterion were registered with the National Institute for Health prospective register for systematic reviews PROSPERO (CRD42022339905).

2.1. Data Sources and Searches

The literature search terms and broad search of 10 databases was undertaken in June 2022 with the assistance of a research librarian (L.R.) using the following search terms and Boolean operators: primary health* OR primary care OR primary health care OR primary medical care OR general practi* OR GP OR family physician* OR family practice OR family medicine OR family care OR family health OR family doctor OR medical specialist OR specialist physician OR office visit* OR ambulatory care OR primary medical care OR medical clinic* OR medical office OR community care OR community

medicine OR community health OR community mental health OR homecare OR home based OR home health OR home visit* Or preventative care OR preventative service* OR preventative program* OR preventative health OR health promotion OR ongoing care OR standard care AND virtual reality OR mixed reality OR augmented reality OR extended reality OT head mounted display* OR virtual environment OR immersive technolog* OR immersive system*. The databases searched included Medline, PsycInfo, Emcare, ProQuest—Computer Science Database, Computers and Applied Sciences—EBSCOhost, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Scopus, IEEE Xplore, Web of Science, and the Cochrane Library. An additional hand search of results from Google Scholar and one institutional library search engine (Primo) was conducted. All searches were limited to the English language and limited to studies published within the last ten years as per Supplementary File S1.

2.2. Eligibility Criterion

Studies were eligible for inclusion if they met the following criterion: (1) full-text articles reporting on randomised controlled trials, observational studies (cohort studies, case—control studies, cross-sectional studies), non-randomised pre/post-test studies, pilot feasibility studies or study protocols, and (2) the study evaluated the use of immersive extended reality technology within the general practice primary care service setting.

2.3. Study Selection

All records retrieved from the primary search strategy were downloaded into Endnote (v20) reference management software for the removal of duplicates and screening. The first round of screening (title and abstract) was conducted independently (blinded) by reviewers (S.F. and D.J.). Records not meeting the eligibility criterion were coded and screened out in hierarchical order as follows: (i) not an eligible study design (NS), (ii) not an eligible population (NP), (iii) not an eligible intervention (NI), and (iv) not an outcome of interest (NO). To ensure consistency of the coding scheme and screening process, the first 50 citations were used to pilot the screening criteria with consensus achieved between the two reviewers. Following the first round of screening, the reviewers then came together to compare Endnote libraries. Any discrepancies with the coding criteria were discussed between the reviewers until a consensus was achieved (arbitration by a third reviewer was not required). All records marked for retrieval during the first round of screening were then retrieved in full text and subjected to a critical review and second round of screening, following the coding criteria outlined above.

2.4. Quality Appraisal

Articles identified for inclusion were independently assessed for quality by two reviewers (D.J. and P.I.) using the Meta-tool for Quality Appraisal of Public Health Evidence (MetaQAT) [18]. The MetaQAT tool was chosen for its ability to appraise specific and generic (heterogenous) studies with high levels of rigor against four main criteria, including (1) relevance to the topic or research question; (2) reliability, assessing the level of transparency and quality of reporting; (3) validity, assessing the risk of bias; and (4) applicability, assessing the application of study findings for public health practice [18]. Written justification for answers (yes, no, unclear, and not applicable) to each criterion was required [18]. No articles in this review were excluded based on quality appraisal.

2.5. Data Extraction

Data extracted from each study included study characteristics (title, author/s, year, and country of publication), study design, methodology (participants, randomisation, blinding, instruments, tools), intervention (type and use of XR technology), and outcomes (analysis, study endpoints, results of adverse events, follow-up). Data extraction was conducted independently by reviewers (P.L., P.M., R.G., D.E., R.R.) and checked by the lead reviewer (D.J.).

3. Results

As per the flowchart illustrated in Figure 2, the comprehensive search strategy identified 1639 records. After duplicates were removed and date limitations were applied, 710 records were subject to the first round of screening (by title and abstract). Following the second round of screening, 11 articles (7 study papers and 4 study protocols) met the review criteria and were subject to quality appraisal. As anticipated in the review protocol, the heterogeneity of included articles, intervention types, and outcome measures precluded any pooling of results for meta-analysis, with the results presented as a narrative synthesis instead.
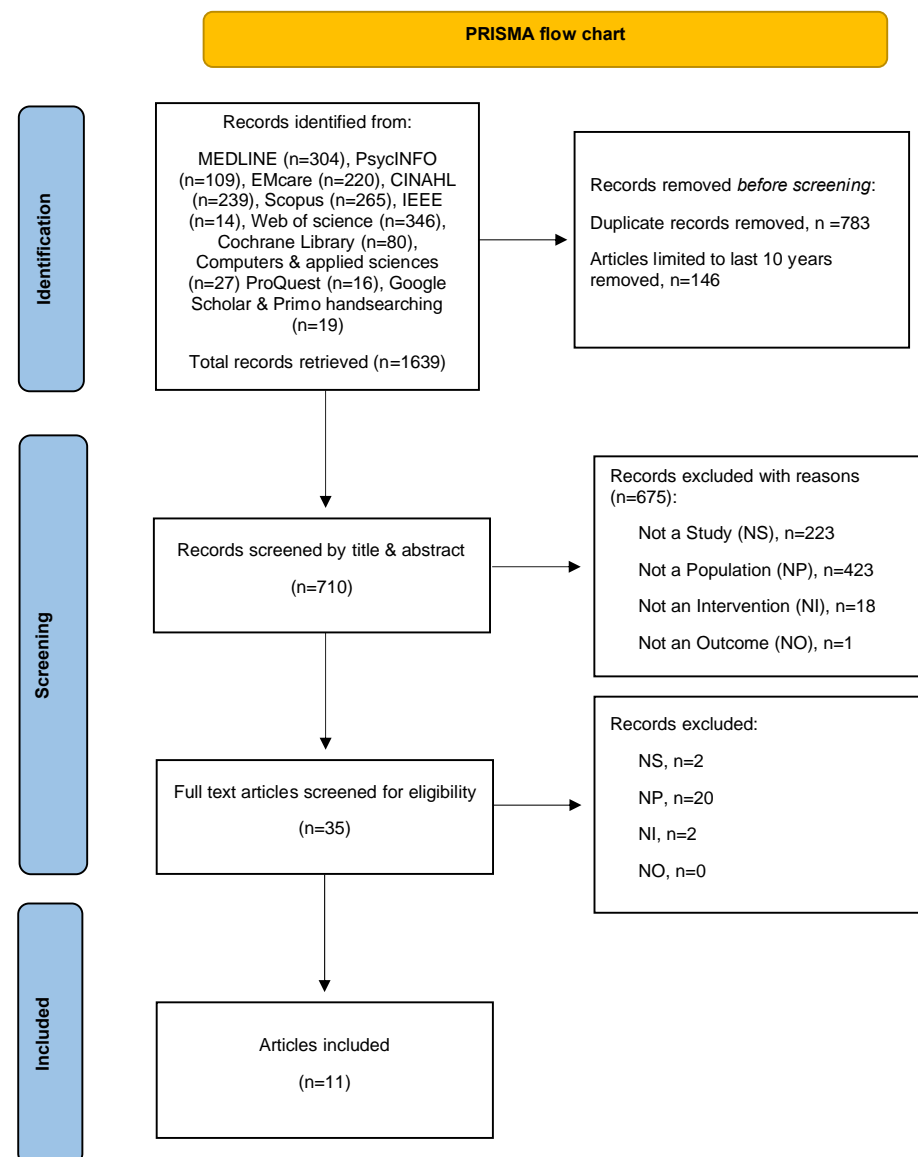

Figure 2. PRISMA flow chart [19].

3.1. Study Characteristics

A summary of all included articles is presented in Table 1. Article publication dates ranged between 2018 and 2022, with studies conducted in Singapore [20–23], Spain [24,25], Brazil [26], Sweden [27], the United States of America [28], Australia [29], and Saudi Arabia [30]. Of the included articles, nine interventions were identified, with all interventions designed for and deployed using virtual reality technology.

Table 1. Study characteristics.

Citation	Application of XR	Application in Primary Care	XR Design and Contents	Study Design and Measures	Study Outcomes
Palomo et al., (2018) [26], Brazil.	Immersive virtual reality (VR). Mindfulness-based intervention (MBI). Mobile phone gear VR HMD.	MBI intervention with VR for adults > 18 years with multimorbidity.	8-week mindfulness-based health promotion program based on teachings by Jon Kabat-Zinn. Meditation room environment. Use of avatars (instructor and user). Instructor avatar conducts the formal practice of mindfulness using 10 imaginative visualisation scenarios.	Randomised controlled trial (RCT) with pre/post and qualitative components. Mindfulness Scale (MAAS). Quality of Life Scale (SF-36). Self-Compassion Scale (SCS). Hospital Anxiety and Depression Scale (HADS). Viability of Technology Scale (VTS). Sociodemographic Questionnaire (DEMO). Qualitative Questionnaire about User Experience (QQUE).	Protocol.
Navarro-Haro et al., (2019) [25], Spain.	Immersive virtual reality. Mindfulness-based intervention. Oculus Rift, DK2 HMD with head tracking.	Adults > 18 years diagnosed with generalised anxiety disorder.	Mindful river world. Users float slowly down a virtual river with trees, boulders and mountains and practice mindfulness skills. Participants listened to mindfulness skill education audios during the VR.	RCT (pre/post) MBI vs. MBI + VR. Screening: Mini international neuropsychiatric interview (MINI). Primary outcome: General Anxiety Disorder 7 (GAD-7). Secondary outcomes: Hospital Anxiety and Depression Scale (HADS). Five Facets of Mindfulness Questionnaire (FFMQ). Difficulties of Emotion Regulation Scale (DERS). Multidimensional Assessment of Interoceptive Awareness (MAIA). Independent Television Company SOP Inventory (TC-SOPI). Visual analogue scale (VAS). The Sense of Presence questionnaire.	N = 39, MBI + VR (n = 19). Primary outcome: Pre/post differences, lower GAD-7 scores, $p < 0.001$. Secondary outcomes: Pre–post improvements on HADS, FFMQ, DERS, and MAIA subscales were evident.
Ellerton et al., (2020) [29], Australia.	Immersive virtual reality. Distraction technique to reduce pain and distress. Google Pixel XL and Google Daydream HMD.	Well children receiving 4-year-old vaccinations (diphtheria, tetanus, pertussis, and poliomyelitis).	Marine adventure with relaxation sequence. Underwater scenes, including gaze-based tracking of virtual fish. Time: 1 min with the vaccination provided approximately 30 sec after commencement of the VR experience.	RCT (VR vs. standard care). Primary outcome: The Faces Pain Scale–Revised (FPS-R). Secondary outcome: Poker Chip Tool. Observer (parents and healthcare providers) ratings of pain and distress: VAS. Qualitative satisfaction survey.	Protocol.
Althumairi et al., (2021) [30], Saudi Arabia.	Immersive virtual reality. Distraction technique to reduce pain and distress. Future Sight All-in-One, VR HMD, Grey, Melkco Inc.	Well children 4–6 years old receiving routine vaccinations.	Animated adventure story (with audio). Time: 2 min synchronised with vaccination procedure.	Non-experimental (VR vs. routine care). Post-intervention measures: Wong–Baker FACES scale. Pain Rating Scale. McMurtry Children's Fear Scale (CFS).	N = 103 (n = 53, VR group). Lower mean pain and fear scores observed for VR group vs. usual care group scores.

Table 1. *Cont.*

Citation	Application of XR	Application in Primary Care	XR Design and Contents	Study Design and Measures	Study Outcomes
Lim et al., (2021) [21], Singapore.	Immersive virtual reality. Cognitive assessment. VR HMD.	Adults 35 to 84 years without cognitive impairment or dementia. Feasibility of using VR to assess cognitive function in primary care.	CAIVRE Cognitive Assessment—a tutorial session followed by 13 VR tasks measuring 6 cognitive assessment domains (using hand gestures and head movements, speech recognition). Embedded automated scoring system. Time: tutorial and assessment < 15 min.	Pilot feasibility study. Feasibility = proportion of participants who completed the entire VR assessment in each age group. Screening: Montreal Cognitive Assessment (MoCA). Pre-VR measures: demographic characteristics, Abbreviated Mental Test (AMT), Mini-Mental State Examination (MMSE), Barthel Index—Basic Activities of Daily Living (BADLs), and Instrumental Activities of Daily Living Scale (IADLs). Post-VR measures: Adapted Spatial Presence Experience Scale (SPES).	Protocol.
Wong et al., (2021) [23], Singapore.	Immersive virtual reality. Cognitive assessment. HTC VIVE Pro with head and hand movements recorded using a Leap Motion controller and voice recognition software.	Cognitively healthy Asian adults aged between 35 and 74 years, (10-year age groups 35–44, 45–54, 55–64, 65–74).	CAIVRE Cognitive Assessment—a tutorial session followed by 13 VR tasks measuring 6 cognitive assessment domains. Embedded automated scoring system. Time: tutorial and assessment < 15 min.	Pilot feasibility study to compare VR assessment completion times with standard cognitive assessment. Demographic characteristics. Proportion completed. Time taken to complete.	N = 99/100. Proportion completed > 90%. Mean time taken to complete VR assessment compared with standard assessment was shorter across all age groups ($p < 0.001$).
Chang et al., (2022) [20], Singapore.	Immersive virtual reality. Distraction technique to reduce pain and distress. Oculus Quest HMD.	Multi-ethnic Asian children aged 4–10 years receiving vaccinations.	SILVER—Soothing Immunization Leveraging on Virtual Reality Experience. VR story centered on the "Burp's Magic Tower" to portray a cosy room filled with shelves of books and other magical items. Time: 2 min with injection administered at 1 min.	RCT pilot feasibility study. Feasibility = recruitment response rate. Children: FPS-R. CFS. Parents and nurse: VAS.	N = 30/34. Recruitment response rate = 88%. Intention to treat analysis. Lower median CFS scores in intervention group (p 0.04). No difference in median FPS-R scores between groups (p 0.13). Lower median VAS scores for parents of children in the intervention group (p 0.04). No difference in nurse VAS scores between groups.

Table 1. *Cont.*

Gibson et al., (2022) [28], Utah, United States.	Immersive virtual reality. Health risk presentation and risk perceptions for prevention of type 2 diabetes (T2DM). Cardboard VR headset utilising smartphones and headphones.	Hispanic adults identified as being pre-diabetic.	Two codesigned 360° videos for use on a smartphone that can also be used with cardboard VR. Video 1: demonstrates how vision worsens with diabetic eye disease. Video 2: a first-person narrative of an individual who progressively develops T2DM, oral health issues, and heart disease. Post-video message: enrolling in the T2DM prevention program (DPP) may prevent negative outcomes.	RCT pilot feasibility study of cardboard VR versus smartphone. Primary outcome was self-reported enrolment in the DPP. Pre-intervention: baseline demographics. 18-item validated risk perception measure. Post-intervention: Feedback survey. 18-item validated risk perception measure. Health literacy measure. Purposive barrier/facilitator survey. Qualitative feedback.	N = 116/209, DPP enrolment 44/116 (37.9%), 25/56 from VR group, and 19/60 from smartphone group. No difference in pre/post-risk perception scores between groups.
Herrera et al., (2022) [24], Spain. Protocol.	Immersive virtual reality. Distraction technique to reduce pain and anxiety. Pico G2 VR goggles with Android tablet connected as controller.	Well children aged 3–6 years of age due to receive: (1) the triple viral + varicella vaccine at 3 years of age; (2) the hepatitis A+ diphtheria–tetanus–pertussis vaccine at age 6.	Leia's World—experience for vaccinations.	RCT VR experience vs. standard care. Baseline demographics. Outcomes (pain and anxiety) Wong–Baker FACES scale. CFS. Purposive post-satisfaction survey.	Protocol.
Lundin et al., (2022) [27], Sweden.	Immersive virtual reality. Cognitive behavioural therapy (CBT) HTC Vive HMD.	Adults >18 years with agoraphobia or previous panic disorder (PDA). Using videoed environments converted to 360° video as a treatment for PDA.	VR-CBT using 360° video virtual environments (VE). VEs were situations feared and avoided by individuals with PDA: inside a subway carriage, a walking tunnel, a busy train station, an elevator, an auditorium, and a tall bridge. 10–12 weekly 60 min CBT program. VR used in weeks 4–9.	Feasibility/acceptability trial. Pre/post and 6 months follow-up. Primary outcomes: Mobility Inventory for Agoraphobia (MIA). Panic Disorder Severity Scale–Self Rated (PDSS-SR). Secondary outcomes: Patient Health Questionnaire-9 (PHQ9). World Health Organization Disability Assessment (WHODAS). World Health Organization Quality of Life questionnaire (WHOQOL). Post-acceptability measure: Client Satisfaction Questionnaire-8 (CSQ-8).	N = 12 (pre/post measures), N = 10 (6 months follow-up). Intention to treat. Primary outcomes: lower mean MIA ($p < 0.001$), PDSS-SR ($p < 0.001$) and PHQ9 scores ($p < 0.001$) pre/post and at 6 months follow-up ($p < 0.05$).
Tan et al., (2022) [22], Singapore.	Immersive virtual reality. Cognitive assessment. HTC VIVE Pro with head and hand movements recorded by a Leap Motion controller and voice recognition software.	Cognitively healthy Asian adults aged between 35 and 74 years (10-year age groups 35–44, 45–54, 55–64, 65–74).	CAIVRE Cognitive Assessment—a tutorial session followed by 13 VR tasks measuring 6 cognitive assessment domains. Embedded automated scoring system. Time: tutorial and assessment < 15 min.	Pilot feasibility study. Age-related aggregated cognitive performance scores (across 6 assessment domains using the within VR automatic scoring matrix) and completion times.	N = 99. Younger participants achieved higher performance scores across all 6 cognitive domains ($p < 0.05$). Younger participants took less time to complete the assessments compared with the older participants ($p < 0.01$).

In terms of the study design, most articles described or conducted randomised controlled trials (RCTs) to test the feasibility and effectiveness of interventions, with or without qualitative participant data collection. The number of participants in these studies ranged between 12 and 116, with the age of participants ranging between 4 years old and 74 years old [20,22,23,25,27,28,30]. All seven study papers were deemed to be transparent and rigorous when assessed using the MetaQAT quality appraisal tool. The four protocol papers [21,24,26,29] received a not applicable rating for the applicability to public health criteria due to an absence of outcome data, as per Supplementary File S2. All interventions were grouped according to their healthcare application and synthesised under three overarching domains as follows.

3.2. IVR for Childhood Vaccinations

Two study papers [20,30] and two protocol papers [24,29] applied VR technology to reduce pain and/or fear associated with childhood vaccinations. Althumairi et al. [30] described the implementation of a 2 min, 3D-animated story experience (using Future Sight HMD by Melko Inc™) amongst children (n = 104) aged between 4 and 6 years. In this study, the VR story experience was simultaneously projected to a practice nurse, ensuring synchronisation of the VR experience with the vaccination procedure [30]. Using a non-randomised trial design, lower mean pain scores (as measured using the Wong-Baker face pain rating scale) and lower mean fear scores (measured using the children's fear scale) were observed for those that received the VR intervention compared to those who did not [30].

The second study by Change et al. [20] conducted a proof-of-concept feasibility and single-centre RCT to test the analgesic effect of their VR intervention. Children in this study (n = 30 aged between 4 and 10 years) were exposed to a 2 min, purpose-built cartoon animation called the Soothing Immunisation Leveraging on Virtual Reality Experience (SILVER). In this study, both the parents and nursing staff anxiety scores were also measured prior to the vaccination procedure [20]. Based on an intention to treat (ITT) analysis, no differences in the children's pain scores (as measured using the revised FACES pain scale) were observed between the intervention and control groups. Statistically significant lower fear scores (as measured using the children's fear scale) were observed for those in the intervention group. Parental anxiety scores were also observed to be significantly lower for those who had children allocated to the intervention group [20].

The study protocol by Ellerton et al. [29] proposed the testing of The Virtual Reality for IMMunisation (VRIMM) experience using an RCT study design to evaluate its effectiveness as a diversional tactic for children receiving their 4-year-old vaccinations. The VR experience was described as a brief (1 min) interactive marine adventure beginning with a relaxation sequence and progressing to underwater scenes that included gaze-based tracking of virtual fish [29]. Vaccination administration occurred after 30 s from the commencement of the experience, with the revised FACES pain scale used as the primary outcome measure. Lastly, the protocol by Harrera et al. [29] also proposed the conduct of an RCT to evaluate the use of VR experience as an analgesic for childhood vaccinations for children aged 3–6 years. A purpose-built VR experience described as "Leia's World" (VR Pharma Immersive Technologies SL) was deployed using Pico G2 VR goggles, with the efficacy measured using the FACES pain scale and children's fear scale [29].

3.3. IVR for Mental Health Therapy or Assessment

Three papers reported on the design and testing of the Cognitive Assessment by Virtual Reality (CAVIRE) intervention [21–23]. Co-developed by a multidisciplinary team, the CAVIRE program (using the HTC VIVE Pro HMD with Leap Motion controller) assesses six cognitive domains, including (1) perceptual motor function, (2) executive function, (3) complex attention, (4) social cognition, (5) learning memory and (6) language.

Wong et al. [23] evaluated the feasibility of the CAIVRE system by comparing VR completion times with a traditional (written) assessment (Montreal Cognitive Assessment)

amongst a cohort of cognitively healthy adults of various ages. Using a non-experimental design, the results indicate that the completion times for the CAVIRE system were significantly shorter than those from completing traditional paper-based assessments across all age groups [23]. Age-related differences in completion times were reported, whereby younger adults completed the assessments quicker than those in older age groups [23]. High levels of acceptability for the CAIVRE system were observed amongst participants, with 92% indicating that they found the CAVIRE system easy to use and 90% indicating that they would be willing to use the system again [23].

Tan et al. [22] further reported pilot study outcomes again using the CAIVRE system amongst healthy adults of various ages. Findings included within this article observed that younger aged adults achieved statistically significantly higher cognitive assessment scores compared with the older participants across all six cognitive domains.

Navarro-Haro et al. [25] and Polomo et al. [26] both proposed the use of VR for the delivery of mindfulness-based therapies. Navarro-Haro et al. [25] conducted a pilot RCT to test a purpose-built VR mindfulness-based skills training intervention (VR-DBT®) that was designed to reduce the symptoms of generalised anxiety disorder in people prone to attention deficits. Participants were randomly assigned to receive either a mindfulness-based intervention in a group setting without VR or a mindfulness-based group intervention and VR [25]. During the VR sessions, participants were seated and fitted with the Oculus Rift DK2 HMD with head tracking. The VR-DBT® experience was described as a "Mindful River World", whereby participants floated slowly down a virtual river with trees, boulders, and mountains whilst listening to mindfulness skills via audio [25]. Using a pre- and post-design, both groups evidenced lower anxiety scores; however, those receiving mindfulness + VR were observed to be more adherent to their treatment when compared with those engaged in traditional mindfulness group-based therapy without VR.

Polomo et al. [26] presented a study protocol proposing the conduct of an RCT to test the feasibility and preliminary efficacy of a VR mindfulness training experience for people with multimorbidity. The VR experience adapted from an 8-week mindfulness-based health promotion program by Jon Kabat-Zinn was suggested to be developed. The VR experience will involve participants being immersed in a meditation room with an avatar of a mindfulness instructor where users can visualise themselves as an avatar within the experience [26]. In this VR experience, the instructor avatar conducts the formal practice of mindfulness using imaginative scenarios. Approximately ten different imaginative scenarios are to be created. Outcome measures for evaluation include a mindfulness scale (MAAS), quality of life (SF-36), Self-Compassion Scale (SCS), depression and anxiety scale (HADS), Viability of Technology Scale (VTS), and a sociodemographic questionnaire [26].

Lundin et al. [27] described the testing of a novel VR–cognitive behavioural therapy (VR-CBT) intervention designed for the treatment of people with panic disorders and agoraphobia (PDA). Developed in collaboration with psychologists, clinical researchers, human–computer interaction researchers, and filmmakers, a 360-degree video was used to create virtual environments (VEs) (Lundin et al. 2022). The virtual environments used for the VR-CBT were situations feared and avoided by individuals with PDA, including being in a subway carriage, in a walking tunnel, in a busy train station, in an elevator, in an auditorium, and on a tall bridge [26]. Environments were selected in collaboration with the patient and were typically those that simulated or resembled situations that the patient found anxiety-provoking in real life. Pre- and post-test measures used for evaluation suggest (n = 12 participants) that VR-CBT demonstrated a significant reduction in agoraphobic avoidance and panic disorder scores from baseline to post-treatment [27].

3.4. IVR for Health Promotion/Disease Prevention

Under the framework of a pilot RCT, Gibson et al. [28] aimed to determine whether presenting brief motivational videos in VR vs. mobile 360° video had differential effects on risk perceptions and enrolment in a diabetes prevention program. Participants (n = 116) in this study were randomised to one of two study groups, namely, mobile 360°

video and mobile VR, and completed pre- and post-evaluation measures. The videos developed demonstrate the possible negative future complications of diabetes [28]. Those assigned to the mobile 360° video group watched the videos on their smartphone (the viewer moved their phone to "look around" the world of the movie), while those assigned to mobile VR watched the videos using their smartphone inside a cardboard VR headset with headphones. The results suggest no significant differences in the risk perception scores in those who used VR compared with using a mobile device [28].

4. Discussion

This systematic review provides a baseline for the use of extended reality (XR) technology implemented within the general practice primary care setting. Although there is a long way to go before the level of technology integration is seamless at the point of care service level or can be provided within the metaverse as envisaged by Musamih et al. [4], this review has determined both practical and novel therapeutic applications of VR technology mediums in this context.

Many of the studies included in this review examined the use of VR as a distraction technique for children receiving immunisations in the primary care setting [20,24,29,30]. Observed reductions in children's fear scores suggest potential improvements in the patient's experience of this procedure. For most children, medical procedures often provoke fear and anxiety. Not only can these procedures hamper recovery and lead to post-traumatic stress symptoms but they may also become the catalyst for the avoidance of health care later in life [31]. The use of VR in this context shows promise and may go some way to reducing fear associated with childhood vaccinations, which improves the overall patient experience and reduces distress in children. Chang et al. [20] revealed a unique finding whereby the use of VR for childhood immunisations also reduced the anxiety levels of the child's parents. That is, just by witnessing less procedure-induced fear from their children, the parents' stress levels were decreased [20]. Therefore, VR as an intervention to reduce stress levels may have a meaningful impact on improving the overall wellness of patients and their families, potentially enhancing adherence to child immunisation schedules.

While the use of VR as a method to alleviate pain associated with childhood vaccinations has yielded mixed results [20,24,29,30], indicating the need for further research investigation, a recent systematic review and meta-analysis by Huang et al. [32] suggests that VR holds promise as a potential analgesic. The review aimed to assess the effectiveness of VR exposure for pain management in terms of pain intensity and types (acute and chronic) amongst adult (>18 yrs) and juvenile (<18 yrs) age groups. A meta-analysis of 26 pooled studies that evaluated pain intensity as the primary outcome (using the visual analogue scale) observed lower pain scores for those in the intervention groups compared with those receiving usual care (WMD -1.62; 95% CI -1.86, -1.38; $p < 0.001$). A subgroup analysis of both juvenile and adult participants also observed reductions in pain intensity for those exposed to VR [32]. An analysis of types of pain additionally observed that those in the VR group evidenced lower pain scores in response to an acute pain stimulus, with no difference in pain scores evidenced for those with chronic pain [32].

The application of VR as an emerging technology in the field of mental health shows the potential to enrich the delivery of traditional assessments and therapies [33,34]. Mental health disorders, such as anxiety, depression, and post-traumatic stress, continue to afflict a significant proportion of global populations, with the availability of qualified mental health professionals suggested to be unable to meet demand, particularly for people residing outside of urban areas [34,35]. Within this context, the feasibility of remotely delivering mental health therapies under the stewardship of a qualified medical practitioner holds promise for overcoming workforce and geographic barriers. In response to these challenges, VR interventions emerge as potential adjuncts to traditional therapies adaptable to various self-guided treatment programs. For example, VR can safely expose patients to anxiety-inducing stimuli, such as crowded spaces or heights, in a safe and controlled manner [27,36,37]. Additionally, mindfulness-based interventions have gained popularity

in mental health treatment, with the use of VR offering a unique platform for which to provide tailored practices that facilitate relaxation, stress reduction, and emotional regulation [25,34].

One distinct application of VR identified in this review is the application of VR for health promotion. The role of VR in confirming and enhancing behavioural strategies, self-motivation, goal setting, problem-solving, and self-reinforcement is emerging [38]. Leveraging this capacity, VR has the potential to augment health promotion efforts in various conditions, including obesity, testicular disorder awareness, smoking cessation, and type 2 diabetes [28,38–40]. However, the application of VR for health promotion in the primary care setting remains in its infancy, with the work by Gibson et al. [28] offering the only perspectives in this context. Gibson's study employed VR as a motivational tool to potentially prevent type 2 diabetes, and although measures of engagement or behaviour change were not conducted, this work demonstrates additional applications of this technology [28]. Further investigation is warranted to explore the efficacy and feasibility of VR interventions within primary care, which can contribute to advancing health literacy.

As evidenced in this review, the application of VR in the general practice primary care setting encompasses a range of hardware and software. Diverse VR hardware ranging from the most basic cardboard VR that uses one's own smartphone [28] to more sophisticated systems, such as the Oculus Quest, were used [20]. Achieving standardisation in VR hardware is an ongoing process, evolving alongside technological advancements. A lack of standardisation can lead to variations in the perceived quality of VR experiences, which influences the overall satisfaction with VR interventions and requires consideration in future research studies. In terms of software, a crucial consideration is the collaborative design or co-design of VR applications in the healthcare context [41–43]. While the principles of collaborative design are acknowledged in VR research, its widespread implementation remains limited. Among the studies included in this review, only four detailed the involvement of patients, clinicians, and developers in the design process [20,21,27,28]. While VR holds promise in enhancing patient experiences, treatment outcomes, and engagement in primary care interventions, the incorporation of collaborative design principles could further amplify their impact.

Limitations

To our knowledge, this was the first systematic review to evaluate the application of XR technologies within the general practice primary medical care setting. Although a rigorous methodology was followed, the inherent value of conducting a meta-analysis within the context of systematic reviews is undeniable [44,45]. Given that the application of XR technologies is in its infancy and very much an emerging field of investigation, a meta-analysis was not feasible and this is a primary limitation of this review.

5. Conclusions

This methodically rigorous systematic review and narrative synthesis laid out the foundations for tracking the evolution and application of XR technologies within the general practice primary care setting. Although an emerging field within this context, our analysis revealed that XR mediums, specifically VR, show potential for reducing the fear associated with childhood immunisations, enabling the delivery of personalised mental health assessments and therapies, and acting as a potential medium for the delivery of health-promoting content. There is immense potential for the future application of XR technologies within the general practice primary care setting to augment current practice, improve adherence to treatment plans, and enhance the overall patient care experience. As technology evolves, healthcare practitioners, XR technology specialists, and researchers should collaborate to harness the full potential of implementing XR mediums within this context to support the delivery of innovative, quality and compassionate medical care.

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