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User experiences of virtual reality technologies for healthcare in learning: an integrative review

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ABSTRACT

The aim of this integrative review was to analyse the usage of different virtual reality (VR) technologies in learning and user experiences (UXs) of these technologies in healthcare practice and education. The integrative review was conducted in spring 2019 by searching eight international databases. The searches retrieved $n = 26$ original articles that were quality checked and included for the review. Three different VR technologies used in the field of healthcare education and practice were identified: haptic device simulators, computer-based simulations and head-mounted displays (HMDs). The haptic simulators were the most often used, whereas the HMD devices were the least-used technology in the field of healthcare. In immersive virtual environments, UX includes ten components. Most of the components were observed in the context of haptic devices and HMD devices, with all ten components being observed with the HMD devices. Almost all of the components were rated as positive. In conclusion, the development of VR technology has enabled the creation of the most comprehensive UXs, thus enhancing skill development, enabling remote access to training and, ultimately, improving patient safety. This review is important as it highlights the need for far more UX research within immersive virtual environments.

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KEYWORDS
Virtual reality; user experience; healthcare; learning; education; integrative review

1. Introduction

Virtual reality (VR) technology is increasingly being used in healthcare education and practice. It has also brought numerous new learning opportunities (Shin 2017), for example in surgery simulation and skill training (Pillai and Mathew 2019). VR integrates real-time computer graphics, sounds and other sensory inputs to create a computer-generated world with which the user can interact (Gregg and Tarrier 2007). VR is a technology which can be used to implement serious games (SGs). SGs are used for purposes other than solely for entertainment (Susi, Johannesson, and Backlund 2007). Previous studies have shown that SGs have potential in terms of professional training. In healthcare, non-technical and technical skills can be learned using SGs (Graafland, Schraagen, and Schijven 2012). Different game elements such as visual appearance, interactivity, immersion, feedback and competition may enhance learning (Koivisto et al. 2016a). VR systems have been proven to improve student performance (Alhalabi 2016). Also, Levett-Jones, Cant, and Lapkin (2019) noted that immersive and experimental simulations were the most effective interventions. Today, new ways of learning are needed because of the different needs of the diverse learners in the healthcare sector, and VR can provide an immersive and effective learning experience for health professionals and students (Ferguson et al. 2015; Foronda et al. 2017). Experiences relating to authentic patient situations are considered the most motivating factors in VR healthcare simulations (Koivisto et al. 2018). Previous research has shown mainly positive attitudes towards training with VR and SGs in the field of healthcare (Salovaara-Hiltunen, Heikkinen, and Koivisto 2019). VR simulation can also provide a safe and conducive environment for healthcare professionals in which to practice new skills and learning from mistakes without harming patient safety (Akhtar et al. 2015; Pillai and Mathew 2019).

Interest in user experience (UX) research is also growing quickly in the field of healthcare and healthcare education. When VR technologies are used in education, the importance of UX has to be noted. As an emerging technology, studies comparing the UXs of the different VR technologies are relatively limited in the field of healthcare. Most of the VR reviews in the field of healthcare have focused on describing the usage and benefits of VR in different sections of healthcare practice and education (e.g. Bracq, Michinov, and Jannin 2019a;

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Pillai and Mathew 2019; Ribeiro et al. 2016; Weiss et al. 2018). There exist no reviews on comparing comprehensively UXs of different VR technologies used in the entire healthcare section in the context of learning. Additionally, there exist no studies on the UXs of VR in healthcare through the lens of Tcha-Tokey et al.'s (2018) ten UX components of which immersive virtual environments consist. Technology has also developed enormously in the last decade. Therefore, it is important to investigate the UXs of these new VR technologies. The subject is important, because UX affects the user's motivation and engagement, which are possibly the most important elements of the learning experience (Panagiotis and Pappas 2016). This review presents examples of VR technologies that offer the most user-centred and user-friendly designs, and thus the best opportunities for learning. The review also reveals how comprehensively the UX components have been studied with the different VR technologies. The aim is to analyse the usage of different VR technologies in learning and the UXs of these technologies in healthcare practice and education. The research questions are as follows:

1. What kinds of virtual reality technologies are used for learning in healthcare practice and education?
2. What kinds of user experiences were there when using the virtual reality technologies?

2. Background

2.1. Virtual reality

VR is a computer-generated simulation of a realistic experience (Mann et al. 2018). VR can be defined as an immersive multimedia or computer-simulated reality (Ferguson et al. 2015) that can create a very immersive experience for the user (Gaba 2007). Mandal (2013) has described VR as a technology where the user interacts with a computer-simulated environment. The VR structure is three-dimensional (3D), which separates it from traditional media.

Presence, interactivity and immersion are the key VR components (Mandal 2013). Presence means the sense of 'being there' in the virtual environment rather than in a real physical place (Johnson, Vorderstrasse, and Shaw 2009; Slater and Steed 2000). Interactivity is defined as an interaction between the user and the virtual environment that enables the user to see the results of his or her actions (Koivisto et al. 2018). Immersion is a psychological state where the person interacts with an environment that provides a continuous stream of stimuli and experiences (Witmer and Singer 1998). There are two types of immersion: mental and physical. Mental immersion refers to a feeling of being involved in the experience, whereas physical immersion refers to the VR system replacing the stimuli to the user's senses (Sherman and Craig 2019). Different levels of immersion and the feeling of presence are defined by the type and quality of these computer-generated impressions. With different technologies, different levels of immersion can be created (Mandal 2013).

According to Mandal (2013), the technologies can be divided into non-immersive desktop VR systems, semi-immersive VR systems and immersive systems. Non-immersive systems are the simplest type of VR with a lower level of immersion. These systems do not need any special devices, only a computer screen. On the other hand, semi-immersive VR systems are an enhanced version of desktop VR. These systems can provide, for example, head tracking and motion. Therefore, the system may improve the user's 'sense of being there' and provide better immersion. Finally, the most immersive systems allow the user to be totally immersed in a 3D world with head-mounted displays (HMDs). This experience may be fully immersive by using auditory, haptic and other non-visual technologies (Mandal 2013).

Computer-based simulations have often been used as learning activities in healthcare practice and education (Bracq, Michinov, and Jannin 2019a). This kind of technology is used especially in nursing education (Foronda et al. 2017; Irwin and Coutts 2015; Koivisto et al. 2018; Padilha et al. 2019; Pons Lelardeux et al. 2017; Verkuyl et al. 2017). These systems can provide real-time visualisation, and the user interacts with the virtual environment, which resembles the real world, but the user is not totally immersed in it (Mandal 2013). Computer-based technologies enable interactive learning and the development of different skills relevant to health professions (Binstadt et al. 2007; Foronda et al. 2017; Peddle et al. 2019). Learners can experience, for example, combining theoretical knowledge with practice (Koivisto et al. 2016b), acquiring non-technical skills (Bracq, Michinov, and Jannin 2019a; Peddle et al. 2019), and receiving computer-generated feedback from their actions (Cant and Cooper 2014).

Haptic simulators have also become a very important training alternative in healthcare because they allow users to interact by adding a sense of touch to the simulation and, at the same time, by creating more immersive learning experiences and improving realism (Escobar-Castillejos et al. 2016; Ruthenbeck and Reynolds 2015). Haptic devices provide force feedback to the user about the virtual objects' physical and movements shown by a computer screen and let the user feel what is happening on the computer screen (Mandal 2013). Haptics help the user to sense a natural or synthetic mechanical environment by touch, by applying forces, vibrations, or motions to the user (Kim, Kim, and Kim 2017). Haptics have been used in the field of medical and surgical training for years (Coles, Meglan, and John 2011; Ribeiro et al. 2016; Ruthenbeck and Reynolds 2015; Ruthenbeck, Carney, and Reynolds 2012) for developing fine motor skills through such simulations (Corrêa et al. 2019).

The most immersive VR systems usually include HMDs and hand controls (Mandal 2013). HMDs in specific fields of healthcare practice and education are still rarely used (Bracq, Michinov, and Jannin 2019a; Fealy et al. 2019; Freina and Ott 2015), however their use is growing rapidly (Weiss et al. 2018). This kind of technology has been adopted in a variety of fields, for example in medical education (Moro, Štromberga, and Stirling 2017; Peden, Mercer, and Tatham 2016) and nursing education and practice (Farra, Smith, and Ulrich 2018; Elliman, Loizou, and Loizides 2016; Kleven et al. 2014). By using a headset, the user can move and turn in the 3D space, as if they were actually there. Also, the digital setting responds directly to the user's movements (Johnson-Glenberg 2018). HMD technology can provide total immersion for the user (Mandal 2013). HMDs with hand controls have been shown to positively affect learning, because of their capability to allow creative and kinaesthetic manipulation of the content (Johnson-Glenberg 2018). The main advantage for all of the aforementioned technologies used in healthcare, is the opportunity to practice in a safe way and learn from mistakes without harming real patients (Elliman, Loizou, and Loizides 2016; Koivisto et al. 2017; Ruthenbeck and Reynolds 2015).

2.2. User experience

The UX concept has a wide variety of different meanings. UX is a mix of a subjective, situated, complex and dynamic concepts. It is a consequence of a user's internal state (motivation, mood, expectations etc.), the characteristics of the system (usability, functionality etc.) and the context where the interaction happens (organisational or social setting, voluntariness of use etc.) (Hassenzahl and Tractinsky 2006). UX contributes to the user's feeling of actually using the product (Sáenz-de-Urturi, García Zapirain, and Méndez Zorrilla 2015) and how the product works when the person interacts with it (Garrett 2011). Zahidi, Lim, and Woods (2014) noted that the UX factors which affect user satisfaction are visual design, a fascinating presentation of the content, updated and credible content, an immersive experience, simple and direct navigation and social media integration. Additionally, Salovaara-Hiltunen, Heikkinen, and Koivisto (2019) noted that UX is a very individual and emotive concept.

Tcha-Tokey et al. (2018), identified ten UX components in immersive virtual environments, namely: presence, engagement, immersion, flow, usability, skill, emotion, experience consequence, judgement and technology adoption. We have already defined presence and immersion in terms of VR components. Engagement is energy in action – the connection between the user and the user's activity consisting of behavioural, emotional and cognitive forms (Tcha-Tokey et al. 2019). The more actively the user participates, the more engaged he or she will be in the situation (Guise et al. 2012) while, flow is defined as a pleasant psychological state of a sense of control, fun and joy (Tcha-Tokey et al. 2019). Usability includes themes such as the ease of use and system efficacy (Fanfarelli, McDaniel, and Crossley 2018). Ease of use refers to the level of effort required to use a specific system (Davis 1989).

Skill is described as the knowledge the user gains by managing his or her activity, and emotion refers to the user's feelings when using the virtual environment (Tcha-Tokey et al. 2019). The users' negative emotions, attitudes and experiences might erode the user's positive attitude toward the VR experience. Using a poor product which essentially unusable may cause frustration, annoyance or even anger in the user (Fanfarelli, McDaniel, and Crossley 2018). Experience consequence means simulator sickness. It involves different symptoms that can be caused by high-fidelity visual simulators such as fatigue, nausea, headaches and eyestrain (Kennedy and Lane 1993). Additionally, judgement is described as the overall experience of the virtual environment (Tcha-Tokey et al. 2019), while technology adoption is a key UX component and refers to the actions and decisions of the user regarding his or her future intention to use the product (Venkatesh et al. 2003).

According to Salovaara-Hiltunen, Heikkinen, and Koivisto (2019), usability is important in players' experiences, and it affects all the other UX dimensions. Likewise, Koivisto et al. (2016b) noted that usability has a great impact on students' learning, for example, in terms of learning effectiveness and their overall learning experience (Orfanou, Tselios, and Katsanos 2015). It has also been argued that authenticity, interaction and feedback enhance learning (Koivisto et al. 2016a). A higher level of immersion may increase learning (Alhalabi 2016; Farra, Smith, and Ulrich 2018; Webster 2016). However, some previous studies have argued against this (Hamari et al. 2016; Makransky, Terkildsen, and Mayer 2019). On the other hand, engagement and challenge positively affect learning (Hamari et al. 2016). Moreover, users are more satisfied with more interactive ways of learning (Dankbaar et al. 2014).

3. Method

3.1. Integrative review

An integrative review is a specific review method which includes both empirical and theoretical literature. Therefore, it can provide a more comprehensive understanding of a specific phenomenon or healthcare problem and it allows for the inclusion of qualitative and quantitative methodologies (Whittemore and Knafl 2005). The analysis of this review included the following steps: (1) identification of the problem, (2) systematic research of the literature, (3) comprehensive evaluation of the data, (4) data analysis and (5) data presentation.

3.2. Search strategy

An electronic search was conducted in spring 2019 with the help of an informatician. The literature search included the following databases: PubMed/Medline, CINAHL, ERIC (EBSCO), Cochrane Library, Web of Science, Scopus, Association of Computing Machinery and the IEEE/IEE Electronic Library, without any limitations. The following search terms and their different combinations were used: 'nursing student', 'healthcare education', 'healthcare professional', 'virtual reality', 'virtual simulation', 'web-based simulation', 'computer-based simulation', 'simulation game', 'game-based simulation', 'screen-based simulator', 'augmented reality', 'virtual patient', 'simulation game', 'user experience' and 'usability' with the Boolean operators (AND, OR). In the review, MeSH terms were also used. In addition, a manual search was conducted on the references of the included articles. No limitations were used in the search.

The inclusion criteria for this review were as follows: (1) qualitative or quantitative studies that involved different disciplines of healthcare workers or nursing/medical students; (2) studies that described healthcare workers or nursing/medical students' UXs or the usability of different VR technologies; (3) studies that described different VR technologies in learning contexts; and (4) studies which had empirical material; and (5) studies where technology was defined by the authors as three-dimensional or as VR. The exclusion criteria were as follows: (1) studies where the technology was defined as two-dimensional or as augmented reality (AR); (2) studies which did not focus on a learning context; (3) studies which were reviews; and (4) studies which described patients' or healthcare teachers' UXs. Non-scientific and anecdotal papers were excluded.

3.3. Literature research outcomes

All researchers in the research group participated in the entire process of this integrative literature review. The search involving the electronic databases identified 741 articles for review. After two reviewers (HM, SH) screened the results by title and abstract, 271 articles were found to be potentially relevant to the full-text review by three authors (HM, SH, JMK). All duplicates were deleted. The next phase involved reading the full-text manuscripts and 26 articles were found which met the inclusion criteria. The final number of articles included in this review is 26 (Table 1 in the Appendix). An additional search was conducted among the references documented in the included papers and there were no more relevant articles found for the full review. Figure 1 shows the whole process of the literature search.

3.4. Quality evaluation

Separate appraisal tools made by the Joanna Briggs Institute (JBI) was used for each included study type: cross sectional (5 questions), quasi-experimental (9 questions), cohort studies (8 questions), randomized controlled trial (13 questions) or qualitative (10 questions) studies (JBI 2019). Two researchers (HM, SH) separately evaluated all the included articles. Subsequently, the researchers reached a consensus about the quality of the included articles. Quality was quantified by assigning a 0 (not mentioned or unclear) to 1 (mentioned) score per criterion question. The majority of the articles were rated as being of fair quality (Benham-Hutchins and Lall 2015; Chow 2012; Chow et al. 2012; Koo et al. 2015; Polivka et al. 2019; Reznek, Rawn, and Krummel 2002; Süncksen et al. 2018) to good quality (Awtrey et al. 2015; Bracq et al. 2019b; Butt, Kardong-Edgren, and Ellertson 2018; Chow 2016; Färber et al. 2009; Girod et al. 2016; Johannesson et al. 2013; Kardong-Edgren et al. 2019; Kidd, Knisley, and Morgan 2012; Kurenov et al. 2017; Leung et al. 2013; Nicolaidou et al. 2015; Padilha et al. 2018; Prasad et al. 2018; Sankaranarayanan et al. 2011; Schvartzman et al. 2014; Schwaab et al. 2011; Verkuyl, Betts, and Sivaramalingam 2019; Vottero 2014) (Table 1 in the Appendix). The main factors which impacted the quality scores related to the lack of clear inclusion or exclusion criteria or to the study setting having been poorly described. Some of the studies did not use validated instruments, and some did not describe the reasons for the loss of follow-ups, or the possible impacts of the results. Upon the completion of the quality appraisal, no studies were excluded.

3.5. Data analysis

General information from the selected studies was gathered and placed in Table 1 in the Appendix. It included

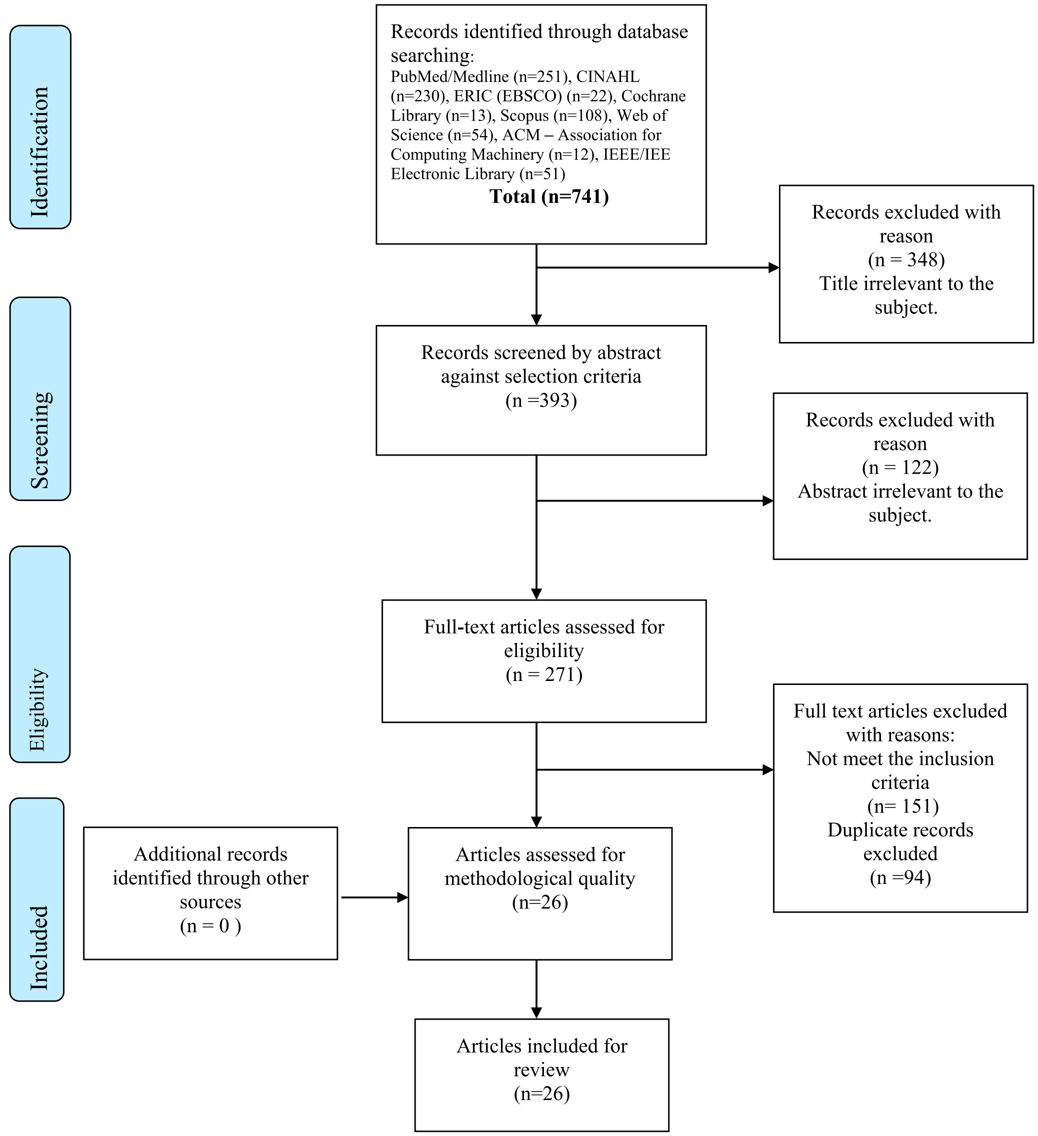

Figure 1. PRISMA Flow diagram of the literature search.

the information about the authors, publishing year, study aim, participants, and methods. First, the researchers identified the VR technologies used in the studies based on their level of immersion according to Mandal (2013) and gathered together the findings, placing them in Table 1 in the Appendix. Then, these technologies were classified into three different groups (Table 1). With the second research question, Tcha-Tokey et al.'s (2018) model of User Experience in Immersive Virtual Environments consisting of ten components was used as a deductive framework for the analysis (Elo and Kyngäs 2008). The deductive framework was selected because the model was newly developed and focused precisely on UXs in immersive virtual environments. In the next phase, the categorisation matrix was built. The data was extracted from primary sources using different data-extraction methods for qualitative and quantitative data (Whittemore and Knafl 2005). Two researchers (HM, JMK) searched for all of the positive and negative statements in the studies that were indicative of Tcha-Tokey et al.'s (2018) ten UX components in virtual environments. These statements were collected in a categorisation matrix. First, every used rating scale was identified. Most of the rating scales were Likert-type scales, a few were System Usability Scales and there was a percent (%) scale. The quantitative data for each study was converted into a percentage ranking from 0% to 100%. The experience was defined as positive if the percentage was higher than 50%. Similarly, it was defined as a negative experience if the percentage was lower than 50%. In the results section, along with quantitative data, qualitative data was analysed with themes using a deductive categorisation matrix.

Table 1. VR user experiences (The numbers refer to the number of the article).

User experience component	Haptic device: 1. Awtrey et al. 2015; 8. Färber et al. 2009; 9. Girod et al. 2016; 10. Johannesson et al. 2013 (Qualitative); 13. Koo et al. 2015; 14. Kurenov et al. 2017; 15. Leung et al. 2013; 19. Prasad et al. 2018; 20. Reznek, Rawn, and Krummel 2002; 21. Sankaranarayanan et al. 2011; 22. Schvartzman et al. 2014			Computer-based: 2. Benham-Hutchins and Lall 2015; 5. Chow et al. 2012; 6. Chow 2012; 7. Chow 2016; 12. Kidd, Knisley, and Morgan 2012; 16. Nicolaidou et al. 2015; 17. Padilha et al. 2018; 18. Polivka et al. 2019; 23. Schwaab et al. 2011; 25. Verkuyl, Betts, and Sivaramalingam 2019			Head-mounted display (HMD): 3. Bracq et al. 2019b; 4. Butt, Kardong-Edgren, and Ellertson 2018; 11. Kardong-Edgren et al. 2019; 24. Süncksen et al. 2018; 26. Vottero 2014		
	Positive	Negative	N/A	Positive	Negative	N/A	Positive	Negative	N/A
Presence	1; 8; 9; 14; 19; 21; 22		13; 15; 20	6; 7		2; 5; 12; 16; 17; 18; 23; 25	3		4; 11; 24; 26
Engagement	8; 14; 21		1; 9; 13; 15; 19; 20; 22	16		2; 5; 6; 7; 12; 17; 18; 23; 25	11		3; 4; 24; 26
Immersion	1; 8; 15; 19; 20; 21		9; 13; 14; 22	23		2; 5; 6; 7; 12; 16; 17; 18; 25	3; 26		4; 11; 24
Flow	8; 19; 22		1; 9; 13; 14; 15; 20; 21	16		2; 5; 6; 7; 12; 17; 18; 23; 25	4; 11		3; 24; 26
Skill	1; 8; 14; 19; 20; 21; 22	13	9; 15	5; 12; 23		2; 6; 7; 16; 17; 18; 25	4		3; 11; 24; 26
Emotion	9; 13		1; 8; 14; 15; 19; 20; 21; 22			2; 5; 6; 7; 12; 16; 17; 23; 24; 25	3; 11		4; 24; 26
Usability	9; 13; 19; 22	20	1; 8; 14; 15; 21	5; 6; 7; 12; 16; 17; 18; 23; 25	2		4; 11	3	24; 26
Technology Adoption	1; 8; 13; 15; 19; 20; 21; 22		9; 14	5; 6; 16; 17; 18; 23; 25		2; 7; 12	3; 4; 11; 24		26
Judgement			1; 8; 9; 13; 14; 15; 19; 20; 21; 22			2; 5; 6; 7; 12; 16; 17; 18; 23; 25	11; 26		3; 4; 24
Experience Consequence			1; 8; 9; 13; 14; 15; 19; 20; 21; 22			2; 5; 6; 7; 12; 16; 17; 18; 23; 25	3		4; 11; 24; 26

4. Results

4.1. Description of the studies

All of the studies were published between 2002 and 2019 (Figure 2). The studies were conducted in the USA (Awtrey et al. 2015; Benham-Hutchins and Lall 2015; Butt, Kardong-Edgren, and Ellertson 2018; Girod et al. 2016; Kardong-Edgren et al. 2019; Kidd, Knisley, and Morgan 2012; Koo et al. 2015; Kurenov et al. 2017; Polivka et al. 2019; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011; Schvartzman et al. 2014; Schwaab et al. 2011; Vottero 2014), Hongkong (Chow 2012, 2016; Chow et al. 2012), Canada (Leung et al. 2013; Verkuyl, Betts, and Sivaramalingam 2019), Germany (Färber et al. 2009; Süncksen et al. 2018), France (Bracq et al. 2019b), Sweden (Johannesson et al. 2013), Greece (Nicolaidou et al. 2015), Portugal (Padilha et al. 2018) and India (Prasad et al. 2018).

The studies were aimed at evaluating the UX of the system (Benham-Hutchins and Lall 2015; Girod et al. 2016; Johannesson et al. 2013; Koo et al. 2015; Nicolaidou et al. 2015; Schvartzman et al. 2014; Schwaab et al. 2011; Süncksen et al. 2018), determining the validity of the system (Awtrey et al. 2015; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011), evaluating the usability or ease of use of the system (Butt, Kardong-Edgren, and Ellertson 2018; Chow 2012, 2016; Chow et al. 2012; Kardong-Edgren

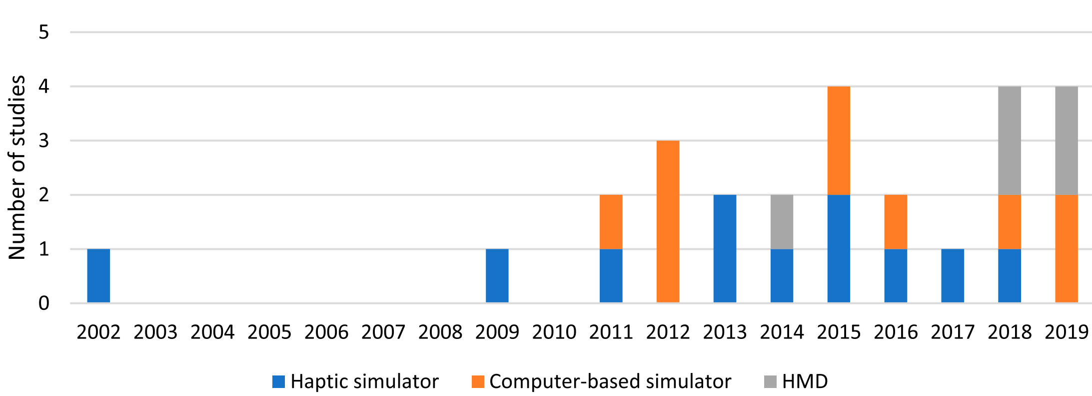

Figure 2. VR technologies used in healthcare in the reviewed studies, by publication year.

et al. 2019; Padilha et al. 2018; Polivka et al. 2019; Verkuyl, Betts, and Sivaramalingam 2019), assessing user acceptance and the effectiveness of the system (Bracq et al. 2019b; Färber et al. 2009; Kidd, Knisley, and Morgan 2012; Kurenov et al. 2017), evaluating the feasibility of the system (Vottero 2014) and developing the system (Leung et al. 2013).

The total sample of studies consisted of qualitative (Johannesson et al. 2013), quantitative (Awtrey et al. 2015; Chow 2012, 2016; Chow et al. 2012; Färber et al. 2009; Girod et al. 2016; Kardong-Edgren et al. 2019; Kidd, Knisley, and Morgan 2012; Koo et al. 2015; Kurenov et al. 2017; Leung et al. 2013; Padilha et al. 2018; Polivka et al. 2019; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011; Schvartzman et al. 2014; Schwaab et al. 2011; Süncksen et al. 2018) and mixed method (Benham-Hutchins and Lall 2015; Bracq et al. 2019b; Butt, Kardong-Edgren, and Ellertson 2018; Nicolaidou et al. 2015; Verkuyl, Betts, and Sivaramalingam 2019; Vottero 2014) papers. The qualitative studies used interviews and blogpost analysis as a method (Benham-Hutchins and Lall 2015; Johannesson et al. 2013). The majority of the quantitative studies used a cross-sectional method (Awtrey et al. 2015; Bracq et al. 2019b; Chow 2012, 2016; Chow et al. 2012; Girod et al. 2016; Kardong-Edgren et al. 2019; Kidd, Knisley, and Morgan 2012; Kurenov et al. 2017; Leung et al. 2013; Nicolaidou et al. 2015; Padilha et al. 2018; Prasad et al. 2018; Sankaranarayanan et al. 2011; Schvartzman et al. 2014; Schwaab et al. 2011; Süncksen et al. 2018; Verkuyl, Betts, and Sivaramalingam 2019; Vottero 2014). There were also quasi-experimental studies (Butt, Kardong-Edgren, and Ellertson 2018; Färber et al. 2009), randomised controlled trials (Koo et al. 2015; Polivka et al. 2019) and a cohort study (Reznek, Rawn, and Krummel 2002).

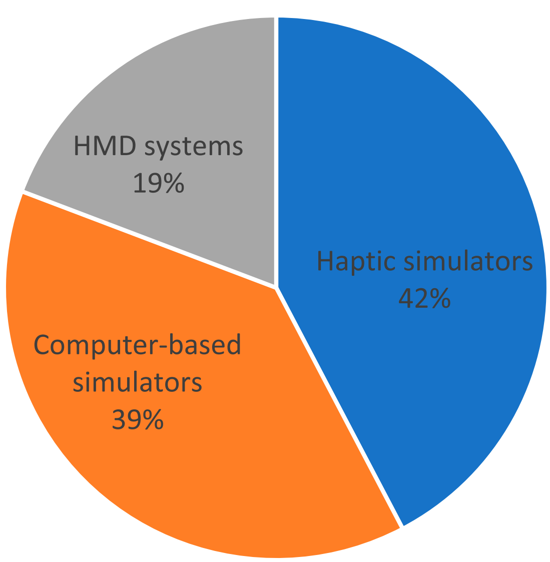

Figure 3. VR technologies used for learning in healthcare in the reviewed studies.

The sample sizes varied from 3 to 426 in the quantitative studies and from 7 to 90 in the mixed method studies. In the qualitative study, the sample size was ten. The participants in the studies consisted of surgeons (Leung et al. 2013; Sankaranarayanan et al. 2011; Schvartzman et al. 2014), medical residents, trainees or fellows (Girod et al. 2016; Kurenov et al. 2017; Schwaab et al. 2011), healthcare students (Benham-Hutchins and Lall 2015; Butt, Kardong-Edgren, and Ellertson 2018; Chow 2012, 2016; Chow et al. 2012; Färber et al. 2009; Johannesson et al. 2013; Kidd, Knisley, and Morgan 2012; Koo et al. 2015; Padilha et al. 2018; Verkuyl, Betts, and Sivaramalingam 2019), and other healthcare faculty (Bracq et al. 2019b; Nicolaidou et al. 2015; Sücksen et al. 2018; Vottero 2014). In some studies, the participants were in mixed groups, for example, nursing students and nursing faculty or medical residents and surgeons together (Awtrey et al. 2015; Kardong-Edgren et al. 2019; Polivka et al. 2019; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002).

4.2. Virtual reality technologies in healthcare

In this integrative literature review, three types of VR technologies were identified as being used for healthcare learning (Figure 3). Haptic simulators were found to be the most used technologies for healthcare learning. The second most used technologies were computer-based simulators. HMD systems were identified in five studies.

Haptic simulators were mostly used in surgical training or medical education (Awtrey et al. 2015; Färber et al. 2009; Girod et al. 2016; Kurenov et al. 2017; Leung et al. 2013; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011; Schvartzman et al. 2014). Some studies were found where a haptic device was also used in nursing studies (Johannesson et al. 2013) and in dental studies (Koo et al. 2015). Different haptic or surgical simulators were used in training for surgery (Awtrey et al. 2015; Kurenov et al. 2017; Leung et al. 2013; Prasad et al. 2018; Sankaranarayanan et al. 2011; Schvartzman et al. 2014), lumbar punctures (Färber et al. 2009), intravenous (IV) insertions (Reznek, Rawn, and Krummel 2002), mandibular fracture reductions (Girod et al. 2016), urethral catheterisations (Johannesson et al. 2013) and tooth preparation (Koo et al. 2015).

Computer-based simulations were mostly used in nursing education or when training healthcare faculty (Benham-Hutchins and Lall 2015; Chow 2012, 2016; Chow et al. 2012; Kidd, Knisley, and Morgan 2012;

Nicolaidou et al. 2015; Padilha et al. 2018; Polivka et al. 2019; Verkuyl, Betts, and Sivaramalingam 2019). In one study, computer-based VR technology was used in training medicine residents (Schwaab et al. 2011). The Second Life three-dimensional online virtual world was the most used computer platform for learning on (Benham-Hutchins and Lall 2015; Chow 2012, 2016; Chow et al. 2012; Kidd, Knisley, and Morgan 2012; Schwaab et al. 2011). Additionally, a few SGs were also identified (Nicolaidou et al. 2015; Padilha et al. 2018; Polivka et al. 2019; Verkuyl, Betts, and Sivaramalingam 2019), such as the VETM, the Body Interact and The Home Healthcare Virtual Simulation Training System. These computer-based virtual technologies were used, for example, in training nursing or healthcare actions (Benham-Hutchins and Lall 2015; Chow 2012, 2016; Chow et al. 2012; Kidd, Knisley, and Morgan 2012), for practicing decision-making skills or making clinical diagnoses (Nicolaidou et al. 2015; Padilha et al. 2018; Polivka et al. 2019; Schwaab et al. 2011; Verkuyl, Betts, and Sivaramalingam 2019).

HMD simulations were used for training healthcare faculty (Bracq et al. 2019b; Süncksen et al. 2018; Vottero 2014) and nursing students (Butt, Kardong-Edgren, and Ellertson 2018) or both (Kardong-Edgren et al. 2019). Three different HMD devices used in learning were identified from the literature: HTC Vive (Bracq et al. 2019b; Süncksen et al. 2018), Oculus Rift (Butt, Kardong-Edgren, and Ellertson 2018; Kardong-Edgren et al. 2019) and CAVE98 (Vottero 2014). The HMD devices were used in medical imaging training (Süncksen et al. 2018), teaching surgical procedures (Bracq et al. 2019b), training on urinary catheterisations (Butt, Kardong-Edgren, and Ellertson 2018; Kardong-Edgren et al. 2019) and teaching about medication withdrawal (Vottero 2014). Figure 4 shows the use of the VR technologies in different contexts.

4.3. User experiences of the virtual reality simulators

In this integrative review, ten UX components in the different VR environments were examined in (1) computer-based technologies, (2) haptic device simulators and (3) HMD technologies (Table 1). Generally, in all three technologies, *usability* and *technology adoption* were the most examined UX areas and mostly ranked as positive experiences. There were only a few negative experiences with every technology. Each of the negative experiences concerned usability (Benham-Hutchins and Lall 2015; Bracq et al. 2019b; Reznek, Rawn, and Krummel 2002) or skill (Koo et al. 2015). *Experience consequence* was the least examined concept in the area of UX. Only one study reported studying simulation sickness (Bracq et al. 2019b).

With haptic device simulators, the components which appeared in the studies most often and were also ranked as positive were as follows: *technology adoption* (Awtrey et al. 2015; Färber et al. 2009; Koo et al. 2015; Leung et al. 2013; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011; Schvartzman et al. 2014), *presence* (Awtrey et al. 2015; Färber et al. 2009; Girod et al. 2016; Kurenov et al. 2017; Prasad et al. 2018; Sankaranarayanan et al. 2011; Schvartzman et al. 2014), *immersion* (Awtrey et al. 2015; Färber et al. 2009; Leung et al. 2013; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011), gaining *skill* in the specific tasks (Awtrey et al. 2015; Färber et al. 2009; Kurenov et al. 2017; Prasad et al. 2018; Reznek, Rawn, and Krummel 2002; Sankaranarayanan et al. 2011; Schvartzman et al. 2014) and *usability* (Girod et al. 2016; Koo et al. 2015; Prasad et al. 2018; Schvartzman et al. 2014). *Engagement* (Färber et al. 2009; Kurenov et al. 2017; Sankaranarayanan et al. 2011), *flow* (Färber et al. 2009; Prasad et al. 2018; Schvartzman et al. 2014) and *emotion* (Girod et al. 2016; Koo et al. 2015) were examined only in a few studies. For example, in Johannesson et al.'s (2013) study, the qualitative results showed that participants felt that they learned to use their hands in a proper way to perform the specific task by using the haptic technology. Participants noted that they were able to feel resistance due to the different degrees of pressure. They also mentioned that the situation felt real and authentic. Again, the studies indicate that the overall *judgement* or *experience consequences* were the UX components that did not appear at all with haptic devices in the studies.

With the computer-based simulations *usability* (Chow 2012, 2016; Chow et al. 2012; Kidd, Knisley, and Morgan 2012; Nicolaidou et al. 2015; Padilha et al. 2018; Polivka et al. 2019; Schwaab et al. 2011; Verkuyl, Betts, and Sivaramalingam 2019) and *technology adoption* (Chow 2012; Chow et al. 2012; Nicolaidou et al. 2015; Padilha et al. 2018; Polivka et al. 2019; Schwaab et al. 2011; Verkuyl, Betts, and Sivaramalingam 2019) were the most examined UX areas and mostly ranked as positive experiences. There were a few studies which indicated the UX's positive effect of gaining *skill* with computer-based technologies (Chow et al. 2012; Kidd, Knisley, and Morgan 2012; Schwaab et al. 2011) and just a few studies showed that users felt *presence* with computer-based technology (Chow 2012, 2016). Otherwise, the other six components (*engagement, immersion, flow, emotion, judgement, experience consequence*) were mentioned only once or not at all. The qualitative data

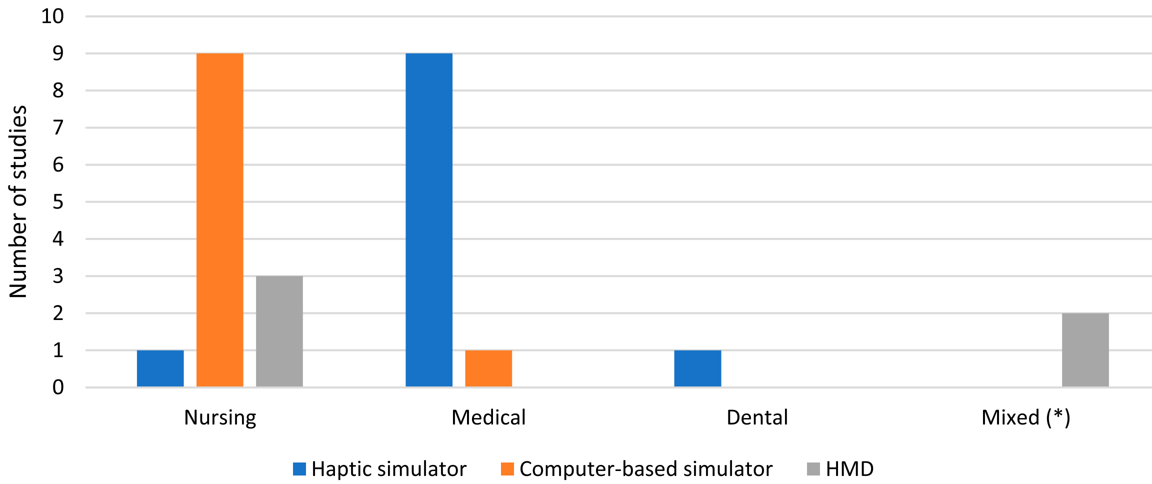

Figure 4. VR technologies in healthcare in the reviewed studies, by learning context.

revealed that participants reported that the simulation table was easy to use and useful for gaining clinical skills (Verkuyl, Betts, and Sivaramalingam 2019). Participants also felt that the simulations were realistic (Kidd, Knisley, and Morgan 2012; Verkuyl, Betts, and Sivaramalingam 2019). However, several concerns related to technical problems such as navigational issues, technology problems related to their personal computer specifications, usability issues or the participant being unable to do some specific tasks (Benham-Hutchins and Lall 2015; Nicolaidou et al. 2015; Verkuyl, Betts, and Sivaramalingam 2019).

With HMDs, every UX component was examined. *Technology adoption* and *usability* were studied the most and ranked as positive (Bracq et al. 2019b; Butt, Kardong-Edgren, and Ellertson 2018; Kardong-Edgren et al. 2019; Süncksen et al. 2018). The studies also noted that *emotion* (Bracq et al. 2019b; Kardong-Edgren et al. 2019), *engagement* (Kardong-Edgren et al. 2019), *immersion* (Bracq et al. 2019b; Vottero 2014), *flow* (Butt, Kardong-Edgren, and Ellertson 2018; Kardong-Edgren et al. 2019) and *judgement* (Kardong-Edgren et al. 2019; Vottero 2014) were evaluated as positive. *Presence* (Bracq et al. 2019b) and *skill* (Butt, Kardong-Edgren, and Ellertson 2018) were noted only in one study, but rated also as positive. In Bracq et al.'s (2019b) study, *experience consequence* (simulation sickness) was rated as low (in Table 1 it is marked as positive). Additionally, the qualitative data identified themes such as fun (*emotion*) and engagement (*engagement*) when using a VR system (Butt, Kardong-Edgren, and Ellertson 2018).

5. Discussion

The aim of this study was to analyse the usage of different VR technologies in learning and the UXs of these technologies in healthcare practice and education. The first research question in this study sought to determine what kinds of VR technologies are used for learning in healthcare practice and education. After reviewing all of the included studies, three different VR technologies used in the field of healthcare were recognised based on their immersion level according to Mandal (2013). All of the studies were written from 2002 to 2019. It should be noted that the technology has developed enormously during the decade. The development of software and hardware has radically increased the possibility of creating realistic immersive simulations. This is why there might also be differences in the UXs. This review is the first to widely examine different VR technologies through the lens of Tcha-Tokey et al.'s (2018) ten UX components. The study contributes to our understanding of the UXs of different VR technologies and helps utilise these findings in healthcare practice and education.

The second question in this research concerned the investigation of what kinds of UXs occur as a result of using VR technologies. The results showed that almost all of the observed UX components were rated as positive. Negative experiences mostly concerned the usability of the technology. The reason for this might be because the usability was the most investigated UX component. This might partly be explained by the fact that a few of these systems were not so easy to use from the users' point of view, and this finding is consistent with that of Fanfarelli, McDaniel, and Crossley (2018). These findings may help us to understand that the newest VR technologies may be challenging for novel users.

One interesting finding in this review was that usability and technology adoption were the most observed UX components in every technology. The result is consistent with that of Salovaara-Hiltunen, Heikkinen, and

Koivisto (2019), who noted that usability plays a very important role in users' overall experience. They pointed out that it affects all the other UX dimensions. Additionally, these results reflect those of Koivisto et al. (2016b), who also found that usability has been shown to have a great impact on learning. Therefore, it can be assumed that, in the future, it will be very important to investigate the usability of the products, especially in the learning context. The existence of numerous usability studies might be the direct consequence of the multitude of different instruments now available for measuring product usability or technology adoption.

In this review, the most used technology in the field of healthcare was the haptic device, which was also confirmed by Coles, Meglan, and John (2011). The results showed positive UXs in many aspects. Comparing haptic device simulators with computer-based simulations, haptic devices showed greater potential for creating more immersive and engaging virtual learning environments. Another finding from the results was that the users also felt more presence and positive feelings around gaining skills with haptic devices than with computer-based simulations. A possible explanation for this might be that haptic devices provide force feedback about the physical properties and movements of the virtual objects (Mandal 2013). These findings may help us to understand, that because of the nature of a more immersive system, haptic devices provide a better opportunity to study about UXs in immersive virtual environments than with computer-based simulations.

The current review indicated that the ten UX components were least examined in relation to computer-based technologies. This may be explained by the fact that, according to Mandal (2013), computer-based technologies are the simplest types of VR applications, which enable a lower level of immersion for the user. These lower level applications stimulate only one or a few senses at a time. The quality of these technologies might often be very low and the information unsynchronised. The results of this study showed that usability issues and technical problems caused frustration in the participants, and earlier studies also confirmed this finding (e.g. Fanfarelli, McDaniel, and Crossley 2018). This might be a reason for the participants stopping their use of the product.

In this review, only five studies were found which used HMDs as a VR technology. However, it has to be noted that these studies were the newest ones in the set, mostly published from 2018 to 2019. A possible explanation for this might be that the HMD technology is comparatively new in the field of healthcare, and thus, there are not yet many studies in this field. However, all of the ten UX components were investigated with respect to HMD devices. This might be due to the HMD devices being the most immersive VR systems and that they enable the user to be totally immersed in the computer-generated world (Mandal 2013). With this kind of technology, the most immersive and realistic experience can be provided for the user. This result reflects former studies such as that of Farra, Smith, and Ulrich (2018) who found that a higher level of immersion may increase learning outcomes, thus providing safer care for patients. This finding suggests that more higher-level immersion systems should be developed for healthcare practice and education for learning. Also, HMD devices were the only VR technologies where the UX component of experience consequence (simulator sickness) was explored. The reason why the experience consequence is investigated with HMD devices may be explained by simulator sickness occurring more often with these technologies. The HMD helmet may be heavy or otherwise distressing for users who are not used to these kinds of devices, which was confirmed by Kennedy and Lane (1993).

The usage of VR technologies for learning in healthcare practice and education has increased, but UX studies in this field are still quite limited. Earlier studies have shown that UX has a great impact on learning and motivation (e.g. Hamari et al. 2016; Koivisto et al. 2016b). However, every VR experience is unique and different, as all the VR events happen in the minds of the users. Every person brings their own capabilities, background, history and experiences to the virtual world in their own unique way (Sherman and Craig 2019). Currently, VR still has some issues with realism and usability, but the rapid development of the technology may clear up this problem in the future. Thus, VR technologies have great potential in the field of healthcare practice and education. In the future, the number and the use of HMDs will grow notably. Additionally, users will become more familiar with and accustomed to HMD technology when it becomes more common. However, the present study raises the issue that more research on the multidimensional concept of UX is still required, as the use of the newest HMD technology differs considerably from other technologies and the quality of the different interactive technologies depends on user-centric designs.

This study has numerous practical implications, from the point of view of educators, healthcare workers, students, organisations and patients. For example, educators in healthcare practice and education may benefit from the results of this review, by being able to choose more suitable technologies for teaching, which could therefore improve learning outcomes. Hence, the more extensively the UXs are taken note of, the better the learning experiences the technology may be able to offer to the users. It follows then, that healthcare practitioners and students could benefit from the results. From an organisational point of view, these findings can be used to help guide better practice to offering the best technologies for learning and skill development, ultimately ensuring safer healthcare. The study highlights the need to understand the relevance of UX. Better UXs lead to better learning which may promote positive patient outcomes, better care and safety practices. With improved education, improved patient outcomes will follow. These findings provide insights for future research to study the concept of UX more widely in the field of immersive virtual environments, not just in terms of usability or technology adoption.

6. Strengths and limitations

The whole review process and the formation of the research questions were carried out systematically and with a high degree of scientific integrity. Although this integrative review represents the existing literature systematically, some limitations might be present. The first limitation relates to the selected search terms. During this review, it turned out that there was an emerging large amount of terminology relating to the VR concept. Thus, the first step was to clearly define the term 'virtual reality'. Our keyword combinations were broad and this integrative literature research was focused on multiple different international databases with the help of the informatics specialist. However, some relevant literature from other sources might have been unlocated, thus reducing reliability. Moreover, there were three researchers involved in the whole literature search process, which may have affected the reliability of this review positively. This second limitation pertains to the risk of bias in including and excluding articles, even with the predefined criteria in place. Additionally, it has to be noted that a relatively large number of studies was discovered because of the wide definition of the concept and that was also why the reviewers had to read hundreds of articles just to be sure that the articles were suitable for the purpose of this review. For the data analysis, there were three researchers who analysed the data, first separately, and afterwards, together, which may have improved the reliability of the data analysis. Finally, all the decisions were made in the research group by all four researchers in concurrence.

7. Conclusion

This study has identified three different VR technologies used in the field of healthcare education and practice: haptic device simulators, computer-based simulations and HMDs, of which haptic devices were used most often. The HMD devices were the least used technology in the field of healthcare. There was some variation in the number of UX components observed with each technology. Most of the UX components were observed in the context of haptic devices and HMD devices. All ten UX components were observed with the HMD devices. In conclusion, the development of VR technology will enable the creation of the most comprehensive experience for its users, thus enhancing skill development, enabling remote access to training, creating novel training methods and, ultimately, improving patient safety. This review of the literature is important in order to highlight the need for more UX research within immersive virtual environments.

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Appendix

Table A1. Description of the studies reviewed.

Author	Aim	Sample	Methods	Apparatus	Quality of the Study
1. Awtrey et al. (2015)	To validate the Virtual Basic Laparoscopic Skill Trainer.	Gynecology residents (n = 18) and gynecologists (n = 9).	Prospective study. Groups of novices, intermediates, and experts. All performed 10 trials of the peg transfer on each simulator. Questionnaire used for subjective evaluation.	Haptic simulator	5/5[a]
2. Benham-Hutchins and Lall (2015)	To determine nursing students' perceptions about the use of SL for nursing education.	Nursing students (n = 20).	Descriptive study with a quantitative survey and qualitative content analysis. Participants kept a journal about their experiences and evaluated the use of VR for nursing education.	Computer-based simulator	6/10[b]
3. Bracq et al. (2019b)	To assess acceptability and usability of a new VR simulator.	Expert scrub nurses (n = 13).	After the participants completed scenario, they answered a post-experiment questionnaire and took part in a semi-structured interview.	HMD	5/5[a]
4. Butt, Kardong-Edgren, and Ellertson (2018)	To explore the ability of VR headgear and haptic technology combined with game-based learning principles.	Nursing students (n = 20).	A mixed method pilot study, exploring the usability, user reaction and skill retention to a game-based VR system.	HMD	9/9[c]
5. Chow et al. (2012)	To describe the development and evaluation of a SL for learning RSI.	Nursing students (n = 206).	Subjects simulated RSI in SL. Students gave feedback using the survey instrument about computer self-efficacy, behavioral intention to use, perceived usefulness and ease of use.	Computer-based simulator	3/5[a]
6. Chow (2012)	To examine the effects of attitude and perceived ease of use on sense of presence in SL.	Nursing students (n = 206).	Four workshops were conducted, and the participants completed the survey instrument.	Computer-based simulator	3/5[a]
7. Chow (2016)	To explore how user variables, combine and interact to predict the level of presence in a 3D VE.	Nursing students (n = 185).	VE and 10 scenarios were designed and developed in SL. Subjects completed survey instrument about perceived usefulness, perceived ease of use, computer self-efficacy, computer self-efficacy and subjective norm.	Computer-based simulator	5/5[a]
8. Färber et al. (2009)	To develop and evaluate a VR lumbar puncture simulator.	Medical students (n = 42).	A pilot user study. Participants in a training and a control group, completed different first training protocols. User acceptance has been evaluated with a questionnaire.	Haptic simulator	8/9[c]
9. Girod et al. (2016)	To evaluate initial user experience with CAS system.	Surgery resident trainees (n = 10).	Participants worked each of the three cases for both the CAD and the CAS haptic system. Data were collected with the User Study Questionnaire.	Haptic simulator	5/5[a]
10. Johannesson et al. (2013)	To investigate the students' experiences about their learning through simulation.	Nursing students (n = 10).	Students performed in pairs urethral catheterization with the simulator. The sessions were videotaped, and the interviews consisted open questions.	Haptic simulator	7/10[b]
11. Kardong-Edgren et al. (2019)	To evaluate the usability of a VR game for sterile catheterization practice.	Nursing students and nursing faculty. (n = 31).	Students and faculty tested and evaluated a VR game using to allow practice of placing a urinary catheter in a virtual patient.	HMD	5/5[a]
12. Kidd, Knisley, and Morgan (2012)	To assess the effectiveness of a SL virtual simulation as a teaching strategy.	Nursing students (n = 126).	Descriptive study. Each simulation consisted of interaction and debriefing portions. Afterwards, participants evaluated the simulation.	Computer-based simulator	5/5[a]
13. Koo et al. (2015)	To assess student perception of haptic-based manual dexterity training.	Dental students (n = 34).	Participants performed tooth preparation. The experimental group performed exercises with the IDEA™ software using a haptic device. Tooth preparations were repeated 2 weeks later. A questionnaire survey assessed the evaluation of the haptic simulation exercise.	Haptic simulator	7/13[d]
14. Kurenov et al. (2017)	To assess user acceptance and effectiveness of a surgeon-authored VR training module.	General surgery residents (n = 14) and surgical oncology fellows (n = 9).	Novices answered a TIPS pre-use questionnaire and adrenalectomy quiz. All participants tested the TIPS adrenalectomy module within the virtual environment. Novices took the adrenalectomy quiz again and answered the qualitative post-use questionnaire and the TIPS evaluation questionnaire.	Haptic simulator	4/5[a]
15. Leung et al. (2013)	To develop a system that will permit the demonstration of a proof of	Highly experienced surgeons (n = 5).	The development of a custom haptic system was followed by evaluation with	Haptic simulator	4/5[a]

(*Continued*)

Table A1. Continued.

Author	Aim	Sample	Methods	Apparatus	Quality of the Study
	concept for the simulation of haptic effects typical of pediatric spine surgery.		surgeons about the realism of the simulated haptic sensations and the usefulness of as a training tool.		
16. Nicolaidou et al. (2015)	To evaluate one scenario of the VETM game.	Ambulance crew nursing personnel ($n = 90$).	After trying the VETM scenario, participants completed an evaluation of the game and provided written and verbal comments.	Computer-based simulator	5/5[a]
17. Padilha et al. (2018)	To assess the ease, usefulness, and intention to use a clinical virtual simulator.	Nursing students ($n = 426$).	An exploratory, descriptive, and cross-sectional study with a quantitative approach. 22 sessions using the simulator was held with demonstration and debriefing.	Computer-based simulator	5/5[a]
18. Polivka et al. (2019)	To evaluate the efficacy, usability, usefulness, and desirability of the training system for home healthcare.	Home healthcare workers, and students in health profession programmes ($n = 74$).	Randomly assigned groups (1) training group and the paper-based training group (2). (1) group completed three modules on a computer. (2) group reviewed identical information in a written hard-copy format. Both groups completed an HH-VSTS Assessment module.	Computer-based simulator	7/13[d]
19. Prasad et al. (2018)	To examine the face and construct validity of a bimanual laparoscopic force-skills trainer with haptics.	Medical residents ($n = 25$) and surgeons ($n = 25$).	Participants performed VR–based tasks and filled out study questionnaire.	Haptic simulator	4/5[a]
20. Reznek, Rawn, and Krummel (2002)	To evaluate construct and content validity, and user perceptions of the CathSim.	Anesthesia and emergency medicine residents and medical students ($n = 41$).	A prospective cohort study. The subjects were divided into novices, intermediates, and experts. All attempted five simulated IV insertions and evaluated the simulation.	Haptic simulator	5/8[e]
21. Sankaranarayanan et al. (2011)	To determine face, construct, and content validity for a novel VR laparoscopic simulator.	Laparoscopic surgery experts ($n = 13$) and novices ($n = 15$).	Subjects used the VR laparoscopic surgery simulator and completed a study questionnaire.	Haptic simulator	4/5[a]
22. Schvartzman et al. (2014)	To evaluate user experience of a newly developed CAS system.	Senior surgeons ($n = 3$).	The participants simulated 3 clinical cases. Questionnaire assessed their experience with the system.	Haptic simulator	4/5[a]
23. Schwaab et al. (2011)	To explore the use of SL virtual simulation technology.	Emergency medicine residents ($n = 27$).	The participants acted the physician avatar and communicated with a faculty examiner who acted as the patient avatar. Afterwards participants addressed perceptions of the utility of SL in medical education.	Computer-based simulator	4/5[a]
24. Süncksen et al. (2018)	To evaluate a novel application of gamification and VR technology to medical imaging training.	Operating room personnel ($n = 41$).	Participants used the VR system and gave feedback about usefulness of the system for medical education and what they liked or disliked the most.	HMD	3/5[a]
25. Verkuyl, Betts, and Sivaramalingam (2019)	To assess ease of use and usefulness in a digital simulation table.	Nursing students ($n = 15$).	Participants worked at the simulation lab in groups. Afterwards they completed the usability survey and semi-structured interviews were held.	Computer-based simulator	5/5[a]
26. Vottero (2014)	To examine the feasibility of VR simulation.	Nursing faculty ($n = 7$).	A proof of concept study. Observed participants completed the scenario and afterwards written evaluation and debriefing.	HMD	5/5[a]

Note: SL = Second Life, UX = User experience, JBI = Joanna Briggs Institute, 3D = 3-dimensional, VR = Virtual reality, VE = Virtual environment, HMD = Head Mounted Display, RSI = Rapid sequence intubation, SUS = System Usability Scale
[a]JBI Appraisal Checklist for Analytical Cross-Sectional Studies.
[b]JBI Appraisal Checklist for Qualitative Studies.
[c]JBI Appraisal Checklist for Quasi Experimental Studies.
[d]JBI Appraisal Checklist for Randomized Controlled Trials.
[e]JBI Appraisal Checklist for Cohort Studies.