



Perspectives of extended reality in nursing- a literature review

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2020 Laurea



Laurea University of Applied Sciences

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Degree Program in Nursing
Thesis
September 2020

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Perspectives of extended reality in nursing

Year	2020	Number of pages	42
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Immersive realities are more and more incorporated into every day and working life of the humanity. However, there was no systematic analysis providing an up-to-date overview on how virtual reality has been used in nursing. This literature review has compiled and organized the latest studies on the application of extended reality (XR) in nursing field, aiming to answer the research question on how virtual reality has been and may be used in nursing. Authors wanted with this paper increase interest in use of XR and its elements: augmented reality, mixed reality, and virtual reality in nursing.

To achieve their research goals, authors have used literature review as a suitable for bachelor level students research method.

The research has shown that XR may be successfully incorporated and be used in a clinical nursing, educational and training purposes as well as in managerial nursing in terms of being a cost-effective tool.

Even though all studies have shown encouraging results and many of them recommended virtual reality as an effective and safe tool to be used in clinical settings as well as in nursing education, no one indicated that their findings would be used in nursing field. Based on these studies, we did not identify any evidence that this technology has been put into practical use in nursing field.

The results have shown that XR is being more and more studied, showing itself of being a very perspective and well-accepted by both professionals and patients and convenient and user-friendly tool. Yet still, there is a need in more trials in all above-mentioned field of nursing. Authors also believe that XR is in a great need of popularization among professionals and patients.

Keywords: augmented reality, extended reality, mixed reality, nursing, virtual reality

List of abbreviations.

AR - Augmented Reality

HMD - Head-Mounted Device

MR - Mixed Reality

UAS - University of Applied Sciences

VR - Virtual Reality

XR - Extended Reality

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1 Introduction

World has step into a digital age some hundred years ago, with a technological progression going with great strides. Both soft and hardware architectures are improved yearly drastically, bringing more and more cooperation and interaction between human beings and machinery (Decker, et al. 2017). Technological solutions becoming more compact, mobile, and specifically designed to open new horizons for even more incorporation into different areas and fields, including healthcare industry. Laptops, tablets, cell-phones are now designed to meet needs of healthcare providers by improving patient safety, improved working process, enabling a use of telemedicine and, of course, protection of personal data. (Lagasse 2018.)

Extended reality (XR), and immersive technologies that are part of it - augmented reality (AR), virtual reality (VR) or mixed reality (MR), are part of current technological trends and changes. They are more and more developed and integrated into different areas and fields, including healthcare and nursing in particular. Recent economic forecasting report estimates that worldwide AR and VR market share in healthcare industry may be up to \$10.82 billion already in 2025. (Research and markets 2019.)

XR projects related to nursing are undergoing worldwide and in Finland. They include most spectrum of holistic care - an essential feature of nursing (Strandberg 2007), such as rehabilitations and health promotion, incl. mental health, for all groups of patients within different nursing settings; educational opportunities for nursing students and professionals (Business Finland n.d.; Sipson 2002; Ferguson, et al. 2015)

Despite of all tendencies and ongoing projects, XR in nursing has not been well researched nor reviewed systematically. In most cases, papers focused separately on VR, AR and MR have been produced, of those not all are research papers. Other wording, currently available papers either do not represent evidence-based approach or they do not cover XR as a whole.

With this thesis authors would like to present an up-to-date synthesis about the situation of applied and potential utilization of the extended reality in nursing within the frames of the same paper.

This work has no working-life partner but based on information authors possess, it may be useful for HUS VR Lab project, Health Incubator Helsinki as well as any other hi-tech projects related to health care in general and nursing in particular both in Finland and worldwide. Also, educational institutions that provide a nursing education may benefit from and utilize results of this work.

2 Background

This paper aims to bring to light the availability and use of virtual and immersive technologies in nursing, for this authors need to first explain what immersive technologies encompasses, how it works and how it has been used so far.

Immersion - with a common sense it refers to a state that involves being or feeling surrounded by something (Nilsson, et. al 2016). One of the ways of reaching immersion is to use immersive technology - a technological solution that can create a merge between physical and virtual worlds (Marr 2019). Immersive technologies referred to within this thesis are virtual reality, augmented reality, and mixed reality. Extended reality is an umbrella term used to describe all immersive technologies. The concept of virtual and immersive technologies started many years ago, in fact, even before computers themselves. (Tersel 2017.)

Back in 1929, Edward Link create the first flight simulator, a complete mechanical machine simulated problems that pilots could experience in a real situation; this simulator was used to train more than 50.000 pilots during WW II. Over time, new machines were being created to produce an even greater sense of reality and immersion. (Virtual reality society n.d.)

In the 20th century, computer technologies advanced rapidly and with them new possibilities for virtual realities. Initially, virtual reality systems were used mainly in entertainment, games, and training. Though, VR possibilities have expanded immensely to many different fields, such as tourism, architecture, and education. In the last few decades, the use of these technologies has also reached the health care area, for education purposes, therapies, and pain management. (Covarrubias n.d.)

2.1 Extended reality

Since 1960's computer scientists have been developing technologies to combine and mix reality and computer create images. In 1969 Myron Krueger - a computer artist, together with other scientists created the "glow flow" a light sound environment that reacts to people within it. Later on, he designed other devices, including Metaplay, Psych space and Video place a combination of projectors and video cameras to produce a virtual environment. In 1989 this technology was available to the users. Since then, it has been in a constant modifications and improvements, and today large companies are investing in XR technologies. (CHRP-India 2018.)

Extended reality is an umbrella term that is used for description of currently available and potentially created in the future immersive technologies (Marr 2019). It includes augmented reality, mixed reality, and virtual reality (Figure 1.).

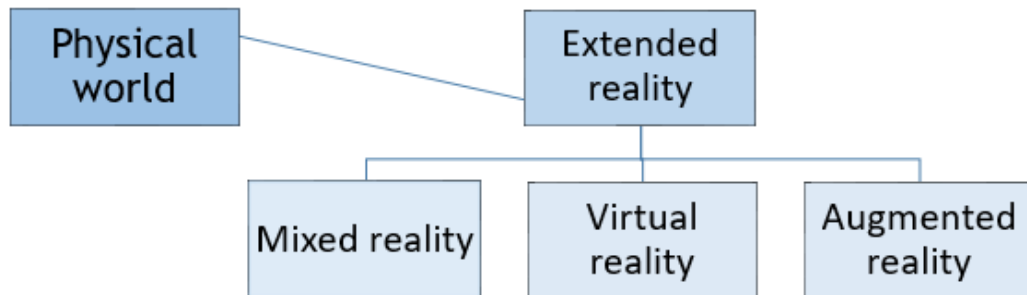


Figure 1: Graphical presentation of XR spectrum

The immersive technology world uses the term extended reality as a concept of fusion of VR, MR and AR (Kinger 2020). While VR, MR and AR attempt to provide different experiences, they all have some similarities such as artificial intelligence and 3D images. It incorporates effects from partial sensory inputs, such as virtual touch in VR to totally immersive worlds. It also uses technologies to provide users with the experience of seeing physical objects in a digital scene or digital objects look real. (Sprinwise 2019.)

The most popular XR technology is the VR, which provides the user an immersive 360-degree virtual environment delivered through headsets and hand controllers. AR creates computer-generated images into the real world, usually by using the camera of tablets and smartphones or the built-in camera of other devices, and the MR can combine real and virtual environments interacting simultaneously. (Eptac n.d.)

The XR technologies have been widely used in education taking 45.73% of the market share, the second is health care and medicine with 19.81%, and others 34.46% is divided between retail, architecture, engineering, construction, manufacturing industries, automotive, transport, travel and leisure (Hire intelligence n.d.).

Amy Peck, an entrepreneur and leader in the field of extended reality technologies, claims that XR will have the next big technological impact in the society after Internet and cell phones (Kuhl 2019).

Despite the promising future of XR, there are also concerns about its use. A research report published in 2019 in the Accenture website mentioned the benefits and the risks these technologies can bring to the users and to the society. In the report they consider the positive impact that XR is making in all fields, as industries boosting productivity, enhancing education and simulated learning, improving customer experiences, and accelerating medical diagnosis enabling less evasive procedure. However, the major concern on the application of XR

technologies is related to misuse of personal and industrial data, since anyone using a mobile phone applicative will be able to scan the information of an individual just by taking a picture, and the data available in social media and others online services will be all revealed to potential cyber-theft. The report also mentioned that prolonged exposure on virtual words could cause new mental health disorders, since the impact of these technologies are still being studied. (Accenture 2019.)

2.1.1 Augmented reality

Augmented reality - a technology that combines real and virtual objects in a real environment that run interactively (Cipresso, et al. 2018).

In 1968 Ivan Sutherland a professor and computer scientist from Harvard gave the first step in the direction of development of AR. He designed the first wearable device that provided the users with sensorial perception. However, the term “Augmented reality” only started to be used after 1990 when the researcher Louis Rosenburg invented the first device using augmented reality systems. This technology started to be used in different fields and for diverse purposes, such as the US Air Force used AR technology to train their pilots with flying simulation; the entertainment industry used AR in a theater projecting virtual images on the real stage. (Poetker 2019.)

Since then, researchers and developers continued improving AR technology to make it accessible to everyone. The AR technology produces virtual images, text, sounds, videos, GPS graphics and animation overlaying the real world, given the users the possibility of interact with those elements without losing the connection with their surroundings. (*Spillers n.d.*) In other words, the users are not immersed in the computer made world and still can see and touch real objects around them (Marr 2019).

This technology uses cameras, mirrors, and sensors to produce images and send these data to a processor. Smartphones, tablets, head-mounted display, AR contact lenses, smart glasses and special AR devices have all components to produce an AR experience. (Think mobiles n.d.)

The use of AR technology seems to be endless; currently the AR application has been used in several different fields. Retail companies uses AR applications to provide the buyers the experience of using the virtual product before they actually purchased the physical one, while the military uses AR devices and games to training soldiers and pilots to boost their perception when acting in dangerous situations. (Bonsor & Chandler 2018.)

There are remarkable AR devices and utilization of AR technology in health care industry; a few examples are a device using AR to show the location of veins (Picture 1), helping

professionals to be precise when stick the vein to start an IV line, another application is used to enable surgeons to see tumors and organs in 3D perspectives without using x-rays avoiding expose patients to radiation (Picture 2). It has also been used in medical school and patient education. (Sosna 2019.)



Picture 1. AR helping find veins (AccuVein n.d.)



Picture 2. AR in X-Ray (Digit n.d.)

2.1.2 Virtual reality

Looking back into the history Virtual reality (VR) and augmented reality (AR) go hand in hand in technological development (Forrest 2018), and sometimes being understood to be the same thing, since both technologies provide 3D images and share many features, and for those who are not familiar with these technologies it's easy to assume that both are VR (Overby 2019).

Although several articles describe VR technology, as a complete immersive experience, that cause the users to become unaware of their real surroundings and focus on the existence inside the computer-generated world (Furht 2008). In fact, virtual reality is divided into three different types: non-immersive, semi-immersive and fully immersive (Poetker 2019).

Non-immersive VR is clearly described by Tsyktor (2019) as “a technology that provides computer-generate environment without a feeling of being immersed in the virtual world”. The technology relies on computer, video game consoles, keyboards, and controllers, for certain games it can also be added wheels, pedals, and speed shifters to provide an improved gaming experience.

The non-immersive VR technology has also been tried in medical field as complementary treatment; one example is in rehabilitation. Scientist from Cambridge University created the ReHabgame, a non-immersive VR game using a motion sense device (Kinect) developed by Microsoft. (Tsyktor 2019.) The ReHabgame was based on neuromuscular rehabilitation system to help patients to recover from upper limb injury (Esfahlani et al. 2018). In other study, non-immersive VR technology was used in elderly rehabilitation with great acceptance, as it does not produce sickness symptoms. The study concluded that non-immersive VR rehabilitation has positive results in elderly patients in training cognitive abilities. (Bavilacqua et al. 2019.)

Semi-immersive VR provides partial virtual interaction without losing the perception of being in different place, for example the flight simulator is composed of visual simulation on screen placed around a real cockpit. It has been mostly used for training and educational purposes using large screen, projection system and computer graphics. In some more advanced semi-immersive technology where real objects interact with virtual ones, it can be considered as mixed reality. (Poetker 2019.)

Fully immersive VR gives the illusion of being inside the virtual world interacting with objects, touching, and changing positions. It requires wearing a head-mounted display, hand controllers or sensory touch gloves. There are many VR games that require a good level of fitness, as the game includes jumping, fighting, and using quick reactions. (Aislinn 2019.)

The science behind immersive VR uses multisensory technology, such as head tracking, motion tracking and eyes tracking that activates human primary senses to make virtual environment feels like real. (The Franklin Institute n.d.). Currently, VR technology has been successful in stimulate visual and auditory senses, but researchers are working to include textures, smells, and sensorial perception (Mendez 2019).

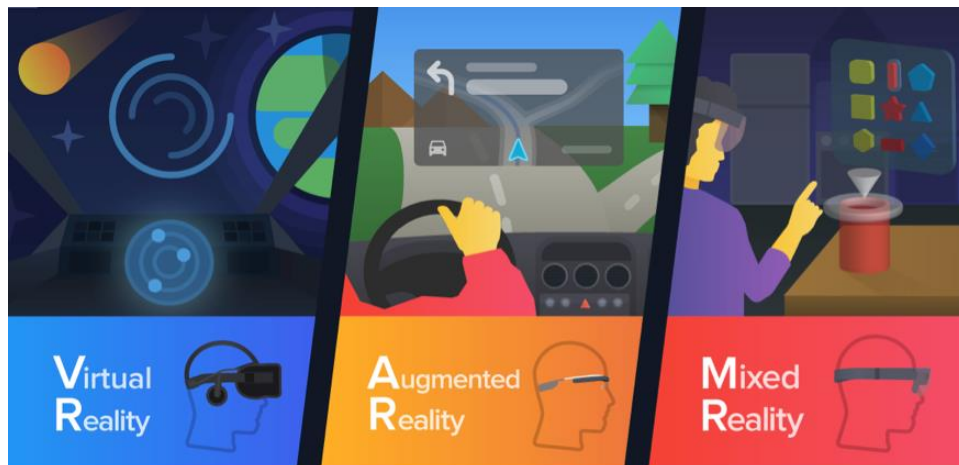
Immersive VR has exceeded games and entertainment and is changing the way people learn. Using more senses in the learning process, the brain stores information and activates memory in several different ways (Hall & Popko n.d). VR has been used in education, military, sports, architecture, healthcare, including surgery, rehabilitation, and treatments of phobia (Tech industry 2020).

2.1.3 Mixed reality

Virtual Fixtures, invented in 1992, was the first immersive mixed reality technology that combined digital objects in a real environment, today called Mixed Reality (Poetker 2019).

Mixed reality is explained as a technology that combines computer processing, human input, and environmental input blending physical and virtual world to the extent when a user can interact in real-time with virtual objects that are overlaid to real world and are able to be as responsive as real actual ones could (Marr 2019; Microsoft Corp. 2018). In other words, it combines features of VR and AR, adding physical interaction to it.

In virtual reality, the user is completely immersed in a world created by the computer, while in mixed reality the user is in a physical space and can interact with virtual objects in real time. More like in augmented reality, where virtual objects overlay the real environment, the difference is that in AR the users cannot interact with the object (Picture 3). For example, in augmented reality the person can see a virtual object on a real table, while with MR the person will be able to pick up and explore the virtual object. (TechTerms 2019.)



Picture 3. Graphical comparison of XR technologies (Medium 2018)

Mixed reality technology uses semi-transparent glasses or headsets with computer screen and cameras to enable mapping, recording, and projecting the physical environment to create a digital display (Noble 2019). It has been used for education, industrial and medical training, engineering, entertainment, and healthcare; however, this technology is still in early stages of development and not widely available (Lanner 2019).

2.2 Earlier applications of XR in nursing

Extended reality, or rather to say - technologies that are under this term, have at least couple decades of attempts to adopt and use them in healthcare field and nursing in particular. Number of papers report that there have been attempts to use extended reality as an assessment, service improving and educational tool as well as a tool in nursing clinical settings. (Kup-sze, et al. 2012; Wüller et al. 2019; Kilmon, et al. 2010.) At the same time, XR is cost-effective (Wanrudee, et al. 2014) and environmentally friendly due to its nature.

The longest and the most solid history of applications and trials has VR, as MR and AR are both relatively new ones to nursing field. As early as in 1997, attempts to apply VR as a distractive tool to increase coping have been made (Kozarek, et al. 1997). A bit later, the technology was successfully used in cross study, aiming to explore if VR in nursing interventions could help women with breast cancer and children with leukaemia. The results showed that VR be useful in reducing symptoms distress and side-effects of chemotherapy, as well as helping to cope with the situation. (Schneider, et al. 2004; Schneider & Workman 2000.)

Despite of promising results and positive feedbacks, participants of earlier trials have reported not only advantages but also disadvantages of technologies included into XR-umbrella in earlier literature. Main challenges mentioned are but not limited to connection and response time challenges, low architectural features - incl. picture sizes or resolutions, physical discomfort during or after a use of a device(s)- incl. vomiting, etc. These challenges

are potentially to be resolved with next generations of soft- and hardwares. (Saleeb & Dafoulas 2010; Wüller, et al. 2019.)

2.2.1 Impact of 5G network technologies on the future of XR in nursing.

Most recent technological situation - 5G network technologies, may have a positive impact towards users experiences and bring an XR use on the next level. A permanent latency less than 20ms is one of a key features that the next network generation brings to XR solutions - a response time will be under the limit when user may experience discomfort, e.g. nausea. Also, 5G has shown to be more stable and faster connection comparing to currently used 4G, thus larger data transmissions are possible with no data transferring failures and slow-downs, that is of being crucial especially for AR and MR . Another important feature of 5G is its capacity to handle with over one million active connections on a relatively small area - 1 km². All these aspects have a direct impact on immersivity of user's experience in healthcare. (Rogers 2020.) Next generation network brings new light to nursing education, LbD practices, at the same time bringing holistic care to the next level (AT&T 2020).

2.2.2 Research coverage

Though use of some XR elements in nursing counts over 20 years, there still is a lack of systematic studies, reviews and synthesis done on the topic of extended reality that are concentrated on the nursing field, both worldwide and in Finland in particular, written in English or any other languages possessed by authors. To be more precise, by the beginning of this literature review, there has been only one scoping review of AR directly connected to the nursing, i.e. Wüller, H. et al., 2019. There are other systematic and scoping reviews but those either not concentrated on the nursing field (e.g. Salmi 2018) or they objected on non-immersive realities (e.g. De Gagne, et al. 2020).

3 Aim, purpose, and research questions

The objective: to present the availability and utilization of extended reality in nursing

Purpose and aim: to increase interest in the topic among nursing field professionals and educational institutions.

Research questions: How extended reality is used or may be used in nursing?

4 Methodology

A literature review has been chosen as a form of a theoretical study for this thesis as by its nature it is a comprehensive summary of previous research about a topic. Literature review describes, summarize, and synthesize findings to show evidence on a meta-level. The literature review gives a prospect for a full understanding about the development in the field seeking to answer to the research question. (Aveyard 2014.)

This work uses a literature review to answer to the research question: how extended reality is used or may be used in nursing? The researches available on extended reality in nursing have been evaluated and synthesized to show evidences on a comprehensive level.

4.1 Information retrieval

Information retrieval has been done based on key words. Data identification and processing took place between March and August 2020.

Record identification has been done in databases, listed in Laurea LibGuides's healthcare resources recommendation list: CINAHL (EBSCO), Cochrane Library, ProQuest Central (Laurea kirjasto, 2020). Further on, PubMed and ScienceDirect (Elsevier) have also been used to supplement identification results from databases screening. Access to all databases have been reached via Laurea LibGuides service or NCBI portal.

Following search limiters and terms have been applied to execute an advanced search in each of above declared database:

- Full text, peer reviewed research articles from academic journals.
- Language frames: English, Finnish, Portuguese, Russian, Ukrainian. These frames are set based on authors' language skills self-estimation; Portuguese-Spanish and Russian-Ukrainian language pairs are possessed only by either of two authors.
- Years: 2015-2020¹.
- Key terms/words: augmented reality (AR), extended reality, immersive reality, mixed reality (MR), nursing, virtual reality (VR).

4.2 Article selection process

Articles have searched by both authors separately. At the identification stage authors have selected articles based on their title, matching them also to inclusion/exclusion criteria rows

¹ Limitation to 5 years is based on the fact that industry of technologies develops extremely fast, thus technological solutions described in more than 5 years old articles may and most probably is no longer be competitive neither in technological aspect nor in economical (Business Finland 2017).

1 and 2 (see Table 1). Articles that have passed title-selection stage, have then been assessed by their abstract. While reading abstracts, authors have once again compared articles to inclusion and exclusion criteria, rows 1-3, and when possible row 4 has been taken into account.

	Inclusion criteria	Exclusion criteria
1	Immersive technology	Non-technological immersion; semi- or non-immersion; use of other than glasses (HMD) technology
2	Original sources	Secondary sources, e.g. systematic and scoping reviews
3	Nursing related	Has little or no connection to nursing, has more medical perspective than nursing
4	Technology has been used in practice and/or is at the late stage of development	Technology has not been used in practice or undergone clinical trial

Table 1: Inclusion and exclusion criteria

After identification and screening stage has been finished, authors have compared their results. Authors have had differences in results number for CINAHL, Cochrane and PubMed. These differences have been discussed and the reason has been found: author 1 did done her identification and screening between March and mid-April, while author 2 did identification and screening in two stages: between April and May and late July-August. Problem has been resolved by author 1 doing additional search for the period not covered in her search.

All articles were in English, thus there has been no need for a separate translation process as both authors equally possess English.

The process follow-up and stages have been done in accordance with PRISMA flow diagram (Figure 2).

Articles approved by both authors at the screening stage have been automatically proceeded to the eligibility stage and further assessment for inclusion for the synthesis text. Articles approved only by either of authors have been brought up into discussion of their eligibility for further inclusion.

The same appliances have been used for the eligibility stage - articles have been double blind-selected, results compared, and articles chosen by both authors have been used for the

synthesis. Articles selection have been done based on all 4 rows of inclusion and exclusion criteria.

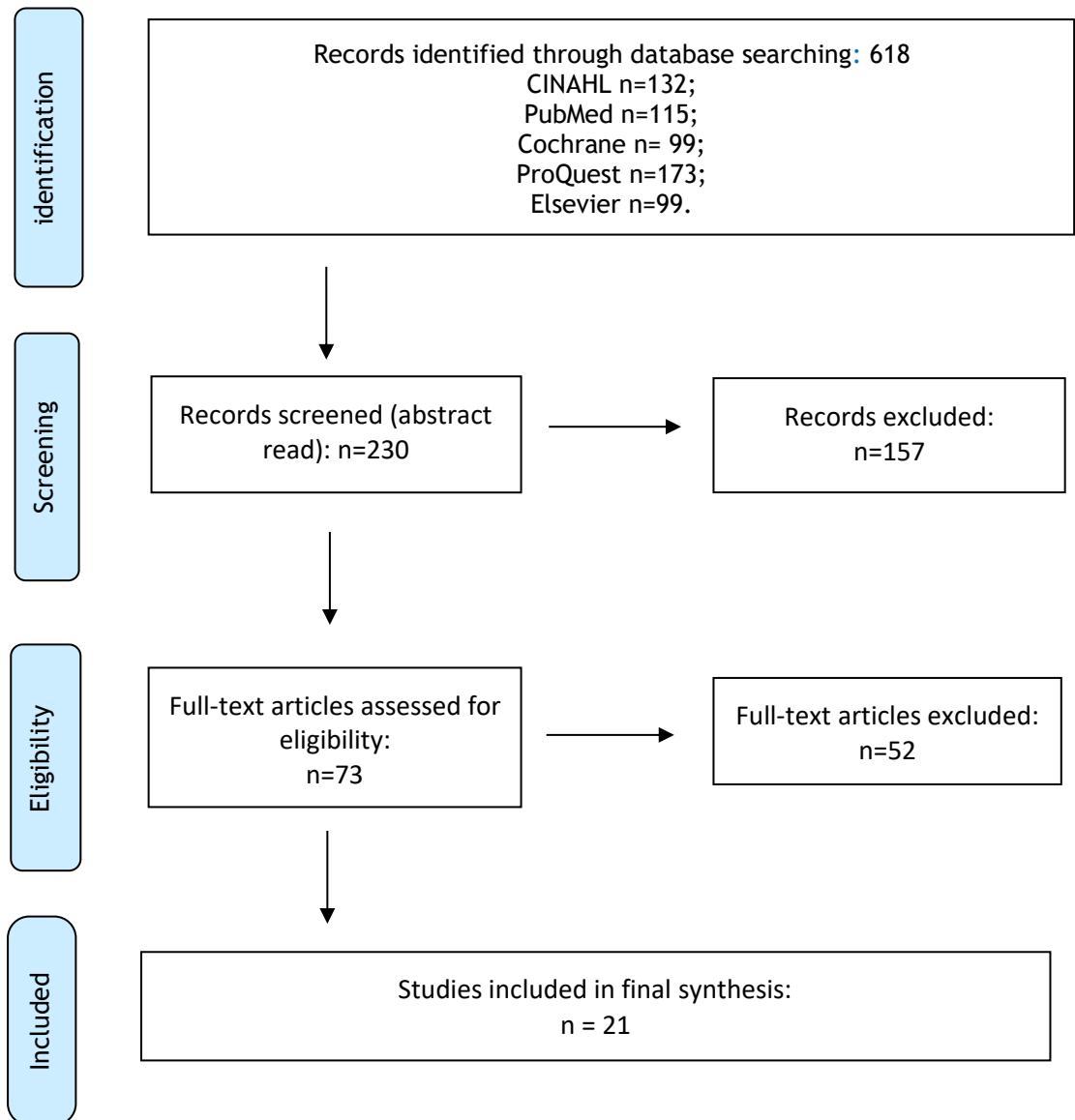


Figure 2: PRISMA flow diagram

4.3 Data Analysis

There are several approaches to data analysis for a literature review. The authors have selected qualitative inductive contents approach as this type of analysis enables to move towards generalization of the data. To create a general data category, authors have organized information through codes, categories, and abstraction. (Elo et al. 2008.) Inductive content analysis consists of three main stages: 1) preparation, 2) organization, and 3) reporting of results (Elo et al. 2014).

As the first stage of data analysis, each selected article has been read carefully and data matrix has been created (appendix 1). To create a data-matrix each of authors has made own notes on preliminary agreed key structure elements of articles: author(s), aim and objective of the study, method and study type, key findings. Later on, a number of participant and possible division into groups have been marked out for a better evaluation of creditability of the work. With a help of a data-matrix authors have presented key points of each shortlisted article.

On the second stage, based on the aims and objectives declared in articles, major field of implementation have been identified. These fields have become major subheadings in reporting of the results.

A mind map has been created by hand on the paper. Afterwards it was transferred into electronic figure, representing systematized key-findings for nursing areas and fields in which acceptability and usability of XR technologies have been tested.

Once previous stages have been completed, an initial synthesis has been written, presenting, and discussing findings, answering the research question (Aveyard 2010, pp. 128-132; Elo et al. 2014).

4.3.1 Critical appraisal

Critical appraisal has been done by assessing literature used in this thesis for relevancy, possible bias, evidence, and quality reliability (Aveyard 2010, pp. 14, 90-92) as well as ensuring it is meeting criteria of reliability and ethical aspects.

Reliability of the sources have been assessed based on the following information evaluation criteria: accuracy, authority, objectivity, currency, coverage (City University of Hong Kong 2019). To ensure that selected articles meet above-mentioned criteria, The Joanna Briggs Institute Critical Appraisal tools have been used. One by one, selected for the synthesis articles have been evaluated with appropriate Critical Appraisal Checklist for an overall appraisal, i.e. to be included or excluded in/from the final synthesis.

5 Findings

After refining the searched material, according to the criteria established in this work, the short-listed studies have been analysed by both authors.

The most significant and evident tendency found is representation of included into XR-umbrella technologies. Prevalent majority of selected articles (n=18) are related to VR

technology, other are focused on AR (n=3). Mixed reality has not been presented among selected articles at all.

Devices used in the studies were restricted by inclusion criteria to HMD - Head-Mounted Devices, with no limitation to materials or components. Studies have shown that workable, cost-effective device may be constructed from cardboards and own phones. Otherwise, devices represented by Google glasses, Oculus (Rift, Quest), Microsoft HoloLens, as well as cardboard based devices (see Appendix 1).

Selected articles, included into the final synthesis, represent controlled trials/studies, pilot studies, mixed method studies.

The main findings in the use of XR in nursing included in this paper have been divided into the different nursing fields and areas of competences (see Figure 3).

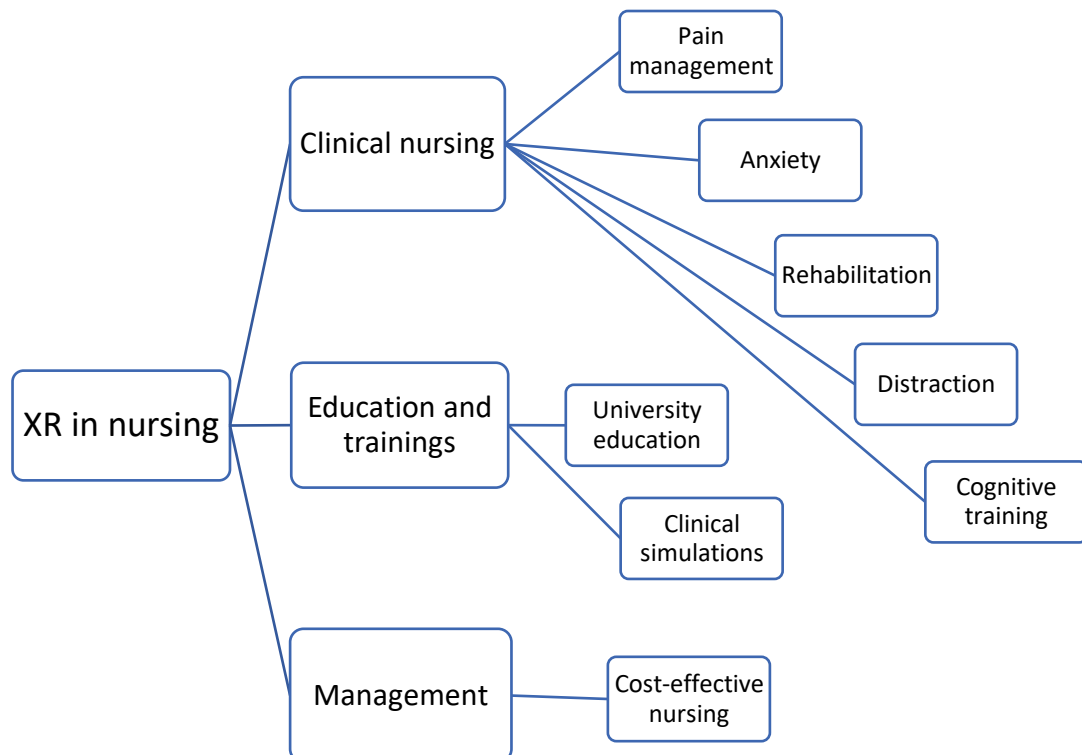


Figure 3: XR in nursing fields and areas of competences

Authors have found that virtual reality has showed positive results as distraction in pain management and during painful procedures (Hua et al. 2015); it also has high level of patient satisfaction compared to others non-evasive methods, particularly children (Walther-Larsen et al. 2019). Virtual reality showed to be safely and effectively used by nurses as supplementary non-pharmacological therapy to treat acute and chronic pain and may help to

reduce the use of opioids (Spiegel et al. 2019). Virtual reality has also been well accepted among elderlies (Liao et al. 2019).

This study has also found that immersive technology (VR and AR) has been widely studied as a pedagogical tool in education and simulation training for nursing students and all health care professionals (Farra et al. 2019; Wu et al. 2020; Berg et.al. 2020; Balian et al.2019; Ball et al.2020; Giordano et al.2019; Butt at al. 2017; Samorson et al. 2019; Ferrandini et al. 2018).

Some studies mentioned the elevated cost of VR devices, especially for home treatment (Garrett et al. 2020); while for training simulation the price is low compared with static mannequin (Giordano et al. 2020).

Among all literatures consulted for this work, the authors observed that nurses have been forefront in the experiments of AR and VR actively participating in the implementation and conduction of trials, as well as been the co-author of many other studies using augmented and virtual realities in clinical settings and nursing education such as Angela B. Samorson, PhD, RN nurse scientist in the Center for Nursing Science and Clinical Inquiry at Brooke Army Medical Center; Sara Ball, PhD, RN Professor at Creighton University College of Nursing; Leslie C. Hussey, PhD, RN Academic program coordinator at School of Nursing College of Health Science, among others. (Somorson et.al. 2019; Ball & Hussey 2020).

5.1 Nursing clinical settings

Up to now, several clinical trials have shown encouraging results on immersive virtual reality to help manage anxiety, controlling pain, distraction for children going through painful procedures, physical rehabilitation and cognitive training for elderlies, all procedures performed by nurses (Yun Hua et al. 2015; Glennon et al. 2018; Walther-Larsen et al. 2019; Spiegel et al. 2019; Garrett et.al. 2020; Gerçeker et al. 2018; Aydin et al. 2019; Liao et al. 2019; Syed-Abdul et al. 2019).

5.1.1 Pain management

Among the studied literature, eight were related to the use of VR to control pain and anxiety caused by painful procedures, especially in children.

The use of virtual reality to minimize pain is grounded on the concept that human brain can process a limited number of information simultaneously. For example, if the brain is engaged in a specific task, the awareness to perform another task is limited (Wahn & König 2017; Wint et al. 2002, cited in Glennon et al. 2018, 546). As virtual reality uses goggles to immerse the user in an activity it serves as distraction of attention on chronic pain and in painful procedures.

Immersive virtual reality has been successfully used to provide cognitive distraction to control acute pain using 3D headsets or goggles to immerse the user in a virtual environment that requires visual, auditory, cognitive and emotional engagement (Garrett et al. 2020).

Following the criteria established for this work, all selected study immerses the users using goggles, headsets, and other devices, in a series of different VR games or VR environments where the users were able to interact with the computer-created world (see Appendix 1).

A comparative study on the effect of VR to distract from pain and anxiety during the procedure of bone marrow aspiration and biopsy used 97 cancer patients aged 48-51 years old. The experimental group used VR goggles and the control group used standard distraction, such as watching television. The results showed that VR is a valuable option for distraction in reducing pain and anxiety especially for patients with previous experience in the use of VR. Nevertheless, the group using VR and the group watching TV experienced similar decrease of pain and anxiety levels. (Glennon et al. 2018.)

Whereas, another study with 120 patients aged 50-52, evaluating virtual reality and specialized TV program for pain management in hospitalized patients, revealed that patients wearing VR experienced superior pain relief than the controlled group. The results were even more evident in patients with severe baseline pain. The study recommended that future trials should assess the use of VR "as an early non-drug option for analgesia". (Spiegel et al. 2019.)

In a qualitative study of patients' perceptions of VR therapy for chronic cancer pain, it demonstrated a mixed result, in which some patients had no effect on their pain and others described their experience as "remarkable". The VR therapy has demonstrated psychological benefits, as participants indicated that the sense of mobility experienced while being able to walk again in VR environment goes beyond pain therapy. Even though most participants found VR therapy to be helpful on pain distraction, they also identified some problems, especially with the headset, such as headset weight and discomfort when wearing eyeglasses. (Garret et al. 2020.)

VR as pain distraction had also positive results on decreasing pain during dressing changes in children with chronic wounds compared to traditional distraction. The study suggested that the use of VR as pain distraction can improve clinical efficiency by reducing the time length during the dressing changes. (Hua et al. 2015.) Another randomized clinical trial involving children used virtual reality as pain distraction during needle procedures. In the controlled group the distraction was led by a specialized paediatric pain nurse and the VR group used a 3D interactive game custom-made for needle procedure situation. They found no difference in pain relief, however, the VR group had 100% satisfaction and would choose VR as distraction for future procedures. (Walther-Larsen et al. 2019.)

Three other comparative studies conducted in Turkey used virtual reality as pain distraction during intravenous procedures in children. The studies revealed that VR is effective on decreasing the perception of pain felt during intravenous procedures, though, one of the studies comparing VR therapy to cold and vibration therapy found no difference between both methods in reducing pain. (Gerçeker et al. 2018; Aydin et al. 2019; Koç Özkan et al. 2019.)

5.1.2 Therapy for elderlies

Two studies carried out at universities and health centres in Taiwan used virtual reality among elderlies (65 years old and over). One study measured elderly's perception and acceptance of VR technology, and the other study compared the effects of VR and traditional method of physical and cognitive training for people with MCI -mild cognitive impairment. (Syed-Abdul et al. 2019; Liao et al. 2019.)

In terms of user's perception and acceptance, 65% found it easy to use, 77% noticed improvement on their mood and motivation and 71,7% intended to use VR in the future. This study also raised some questions that need to be taken into account when developing applications for elderly, such as: usability must be easy to use; be useful, games must be designed to meet their needs and interests and promote social interaction. (Syed-Abdul et al. 2019.)

As for the use of VR for physical and cognitive training, it also showed superior results compared to the traditional method used in the study (Liao et al. 2019).

The results of both studies were optimistic regarding the use of virtual reality among elderlies (Syed-Abdul et al. 2019; Liao et al. 2019).

5.2 Nursing training and simulations

Among the studies reviewed in this work various have been done on the use of virtual reality and augmented reality in health care education, especially in clinical simulations, training nurses' practical skills in clinical procedures, communication, prompt response in stress situation, anxiety control and test nurses' abilities and adaptation to this new technology. The studies have measured different factors, including the students' acceptance, usability, training outcomes and cost-effectiveness. (Balian et al. 2020; Ball & Leslie 2020; Giordano et al. 2019; Butt et al. 2017; Samorson et al 2019.)

Overall, compared to traditional training simulation, VR and AR has demonstrated equal or higher effectiveness on practical training and skills acquisition in procedures, such as, airways insertion (Somorson et al. 2019), cardiopulmonary resuscitation and resuscitation in opioid-related overdose, combined with providing quality CPR (Giordano et al 2019). These simulations have used systems developed specifically for each training situation.

Virtual reality has showed to be a valuable tool for nurses and medical trainees to exercise control on anxiety levels. One study using a tailor-made VR game for training needle sticks prevention and sharp objects injury mentioned that all participants improved their performance and presented less anxiety levels during needles procedures. (Wu et al. 2020.)

However, another comparative study measured the effects of augmented reality on nursing students' anxiety level on clinical environment has demonstrated no substantial difference between AR and traditional method. Still, the study acknowledged that AR can be a valuable training system, and it has the benefit of saving faculty time as it can be used multiple times providing consistent content. (Ball & Hussey 2019.)

5.3 Cost-effectiveness

The studies have showed that costs for a VR or AR systems vary according to its complexity - it can be a simple mobile phone device introduced in a cardboard googles (Giordano et al. 2020) or a more advance and sophisticated systems such as the one for CPR training, comprised of an AR system with immersive multi-sensory tools delivered by a mannequin connected to AR headset. The system analysed the chest compression rate, depth, and recoil into a holographic image of the circulatory system. It showed the blood flow to the vital organs according to the quality of the chest compression performed and provided a CPR quality scores at the end. (Balian et al. 2019.)

Intraoperative management of anxiety, pain and vital signs has been shown to be less expensive with a use of a VR. At the same time, the same study shows little or barely no difference in reducing anxiety in the intraoperative period. (Sahin & Basak 2019.)

VR simulation is more affordable and accessible for dissemination than the hybrid mannequin, providing the same positive results and higher user's satisfaction (Giordano et al. 2020). Another study mentioned that their VR system were developed on a small budget and the cost of the system had already decreased since its creation, which made the system progressively cost effective. It was also mentioned that Virtual reality training and simulations provide opportunity for nurses to practice more often in shorter time. (Butt et al. 2018.) AR 360 can be a valuable method of orientation that saves faculty time and ensures more consistent content (Ball & Hussey 2019).

VR and AR technologies for training need to be seen as long-term investment, since the high costs occur in the implementation of the system and in the purchase of the equipment. After three years the cost of training becomes lower than traditional methods using mannequins. The high initial cost of VR become a cost saving as the number of trained staff increases and the training is repeated. (Farra et al. 2019.)

6 Discussion

The results presented in this work are in accordance with older researches information: such areas of clinical nursing as pain management, coping techniques have been studied earlier (Kozarek, et al. 1997; Schneider, et al. 2004; Schneider & Workman 2000) and are being closely under researchers' attention nowadays (Gerçeker et al. 2018; Aydin et al. 2019; Koç Özkan et al. 2019; Garret et al 2020).

Earlier studies have constantly reported adverse effects of XR technologies due to its developmental stage and predicted improvements related to technological progression (Saleeb & Dafoulas 2010; Wüller, et al. 2019; Rogers 2020). Development of the technologies, both XR devices and related to its functionality, has bring new level of a comfortable use (Balian, et al. 2019; Berg & Stenbsbekk 2020; Samorson et al 2020; Spiegel et al 2019). Nevertheless, some papers have reported adverse effect related to use of XR technology. Adverse effects mentioned were dizziness, nausea. (Walther-Larsen et al. 2019; Balian, et al, 2019; Spiegel, B., et al. 2019; Garret et al 2020.)

Augmented reality and virtual reality as a training and simulation instrument was very well received among student nurses, medical trainees, and health care professionals. In general, participants showed a high level of satisfaction and adaptation to the technology with little or no adverse reactions, cyber sickness. (Butt et al. 2017; Samosorn et al. 2019.) They also perceived the experience as realistic with high fidelity visualization and immersion, recognized as helpful tool for training/simulations and considered using these technologies in the future (Balian et al. 2019).

Despite the positive results in clinical trials on the use of VR and AR to reduce pain and anxiety, the authors of this study have not found, in the reviewed literatures, confirmation that these technologies have already been recognized and approved to be officially used for treatments in clinical settings as a part of clinical protocol.

Nevertheless, some innovative hospitals are putting the technology into practical work and heading revolutionary experiments, such as the Hoag Hospital in Newport Beach, USA. The Hoag Hospital is one of the first to bring VR technology in pain management to clinical settings. (Milling 2020.)

6.1 Trustworthiness and validity

To ensure that these works has a high level of trustworthiness and validity, all stages and steps have been documented in detail, with constant (re-)assessing steps, details, sections of this thesis independently by each author and together. Also, critical appraisal and ethical questions have been borne in mind through all the thesis writing process.

6.2 Ethical considerations

ARENE UAS ethical guideline and Laurea UAS internal guidelines has been used as a guide. Ethical considerations in this work has mainly been related to use of the intellectual property and shall be respected by a proper quotation and referencing of the original work, aiming, thus, to avoid plagiarism in any forms and extents.

6.3 Limitations

Authors skills and knowledge in a research field are limited to bachelor level skills and knowledge.

In terms of the research results, this work is limited to availability of full-text articles. Despite University provides students access to multiple databases, authors have faced impossibility to extract full-text for all accepted by a title articles.

6.4 Conflict of interests and biases

Authors declare no conflict of interests as well as no biases. None of the authors is in contact with XR hard- or software related companies.

7 Conclusions

The results of this literature review indicated that immersive reality is being continuously studied and recommended as tool for clinical nursing and nursing education.

We found 21 clinical trials presented in the last five years which demonstrates the multiple applications of virtual reality in nursing. The researchers focused on specific areas, such as distraction during painful procedures, acute and chronic pain management, physical rehabilitation, cognitive training for elderlies and help to minimize anxiety. A large part of these studies were dedicated to nursing education and clinical simulations for health care professionals. (see Appendix 1.)

In the development process of this literature review, it was observed by the authors that in all studies and clinical trials selected for this work, the software industry, computer scientists, universities, educators, hospitals and healthcare professionals have been involved in projects and clinical trials to help design immersive virtual reality applications and interactive VR games tailored to attend patient's and health care professionals' specific needs. For example, the sophisticated system created for training hospital workers for evacuation (Farra et al. 2019).

The authors believe that findings presented in this work may be valuable for further researches, as this literature review offers a panoramic scenery of the latest findings on the vast possibilities of use virtual reality in nursing. They also suggest that clinical trials should be intensified in order to strengthen the credibility and increase visibility of XR as a treatment option for patients, as well as education and simulation training for healthcare professionals.

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Appendices

Appendix 1: Data matrix (details of included studies)

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No	Author(s), year, and title	Aims/objectives	Methods/type of the study	Number of participants	Technology used and field of implementation	Major findings
1	Farra, et al. 2019. Comparative Cost of Virtual Reality Training and Live Exercises for Training Hospital Workers for Evacuation.	To provide cost analysis of one live disaster exercise compared to development and implementation of the VR exercises.	<i>Live exercises/ Economic Evaluation</i>	160 staff hours	VR: Oculus HMD with an Xbox controller Cost-effective management	VR can be an effective training medium. VR group significantly outperformed their peers trained with Web-based clinical update modules. Larger numbers of staff on a convenient schedule and its long-term cost savings. Does not need patient care spaces, thus revenue from patient places is not lost.
2	Spiegel, et al. (2019). Virtual reality for management of pain in hospitalized patients: A	To measure the impact of on-demand VR versus “health and wellness” television programming for pain in hospitalized patients	A prospective, randomized, comparative effectiveness trial	120 subjects (61 VR; 59 control)	VR: Samsung Gear Oculus headset Clinical nursing	VR helps to significantly lower the pain level. Patients from VR group are more satisfied with audio-visual experiences.

	randomized comparative effectiveness trial.					<p>No significant difference in satisfaction of stay in hospital between VR and control groups.</p> <p>No difference in opioids consumption in pre-/post intervention periods.</p> <p>3 patients in VR reported HMD-related dizziness.</p>
3	<p>Syed-Abdul, et al. 2019.</p> <p>Virtual reality among the elderly: a usefulness and acceptance study from Taiwan.</p>	To investigate the acceptance and use of VR by the elderly	Mixed method pilot study	30 older adults	<p>VR: Vive htc VR system</p> <p>Clinical nursing/gerontology</p>	<p>Older people have positive perceptions towards accepting and using VR to support active aging.</p> <p>Elderlies perceived VR to be useful, easy to use, and an enjoyable experience.</p> <p>Participants have shown positive attitudes toward adopting this new technology.</p>
4	<p>Liao, et al. 2019.</p> <p>Effects of Virtual Reality-Based Physical and Cognitive Training on Executive Function and Dual-Task Gait Performance in Older</p>	To assess the effects of VR-based physical and cognitive training on executive function and dual-task gait performance in older adults with MCI, as well as compare the VR-based physical and cognitive training	A single-blinded (assessor) randomized controlled trial	<p>Started: 42 participants (21 VR; 21 CPC)</p> <p>At the end: 34 participants</p>	<p>VR: headset + Kinect system</p> <p>Clinical nursing/gerontology</p>	<p>Significant improvements in executive and single-task/motor dual-task gait performances within both groups.</p> <p>Improvements in cognitive dual-task gait performance in VR group.</p>

	Adults With Mild Cognitive Impairment: A Randomized Control Trial.	with traditional combined physical and cognitive training.		(VR 18; CPC 16)		
5	Wu, et al. 2020. Effect of virtual reality training to decreases rates of needle stick/sharp injuries in new-coming medical and nursing interns in Taiwan.	To evaluate the effectiveness of game-based VR training on universal precaution (UP) for occupational NSI prevention through Gagne's flow	Mixed method prospective and pre- and post-comparison study	59 new-coming nursing and 50 medical interns	VR: headset Studying/training	All trainees have improved their performance and decision making after VR training. Anxiety level regarding occupational needle stick and sharp injury prevention has lowered. VR game reduced the needle stick or sharp injury rates in the first 2 months of nursing and medical internship.
6	Garrett, et al. 2020. Patients perceptions of virtual reality therapy in the management of chronic cancer pain.	To investigate the efficacy of VR interventions as a practical therapeutic intervention in the self-management of the chronic pain associated with cancer	Two-armed and participant-blinded trial, part of the bigger study	23 participants were invited, with 12 completing the focus group	VR: headset Clinical nursing	Mixed results in the use of adjunctive VR therapy to manage chronic cancer pain. Majority of respondents found it to be beneficial. Pain management is a highly complex and individualized process.
7	Berg & Steinsbekk. 2020. Is individual practice in an immersive and interactive virtual reality application	To investigate if individual self-practice of the ABCDE approach in an immersive and interactive VR application gave non-inferior learning outcome compared to	A non-inferior parallel group randomized controlled trial	289 participants (VR 149 and TP 140).	VR: Oculus Rift S or Oculus Quest HMD and hand controllers	Individual self-practicing the ABCDE approach in VR was non-inferior to individual self-practicing with TP.

	non-inferior to practicing with traditional equipment in learning systematic clinical observation? A randomized controlled trial.	using traditional equipment (TP) in first year medical and nursing students.			Study/training	Respiratory frequency was better reported in VR group. VR method was liked more than traditional and founded to be usable.
8	Balian, et al. 2019. Feasibility of an augmented reality cardiopulmonary resuscitation training system for health care providers.	To test the feasibility of an AR CPR training system (CPReality) for health care providers (hcps)	Feasibility trial	51 participants (RN 34; Physician 8; AP RN 2; Technician 2; Pharmacy 2; Other 3)	AR: Microsoft HoloLens Studying/training	High quality CC delivery was feasible using the AR CPR training system. AR training was received favourably by most participants.
9	Sugiura, et al. 2019. The Use of Augmented Reality Technology in Medical Specimen Museum Tours.	To optimize the AR techniques with which a real specimen in the museum is viewed to establish a new exhibition description and (2) to compare two AR systems alongside traditional description panels, with an additional learning experience evaluation. In each process, the present study prioritized the results from a subjective evaluation through	Mixed	84 participants (control 32; tablet AR 32; HMD AR 20)	AR: HMD Study/training	AR-based system is effective tool for exhibition descriptions. AR increases students' motivation for learning.

		questionnaire surveys in order to focus on user-centred design				
10	Hua, et. al. 2015. The effect of virtual reality distraction on pain relief during dressing changes in children with chronic wounds on lower limbs	Investigate the effect of virtual reality distraction on alleviating pain during dressing changes in children with chronic wounds on their lower limbs	Randomized control trial	65 children	VR: HMD Clinical nursing	VR distraction significantly alleviate the pain in children before, during and after the dressing changes.
11	Walther-Larsen, et al. 2019. Immersive virtual reality for pediatric procedural pain: Randomized clinical trial	Investigate patient satisfaction and pain reduction by using a three-dimensional VR interactive game as a distraction	Randomized clinical trial	Started: 64 children (32 control group; 32 VR group) Ended: 59 children (31 Control group; 28 VR group)	VR: goggles Clinical nursing	No difference in pain scores, Higher level of satisfaction with using the VR .
12	Ball & Hussey. 2020. The effects of AR on Prelicensure Nursing Student's anxiety levels	To explore the viability of augmented reality (AR), as a platform to prepare students and decrease their anxiety levels when entering a new environment	Pretest / posttest quasiexperimental design	82 qualified participants (50 AR; 32 faculty-led orientation)	AR: 360 photosphere Study/training	AR 360 can be a valuable method of orientation. Saves faculty time and ensures more consistent and uniform content.

13	Glennon, et al. 2018. Use of virtual reality to distract from pain and anxiety	To determine the effects of a virtual reality intervention on pain and anxiety in patients undergoing a bone marrow aspiration and biopsy procedure.	Quasiexperimental study	97 participants	VR: Goggles Clinical nursing	Virtual reality goggles may be a feasible, non-invasive alternative to traditional pharmacologic treatment.
14	Giordano, et al. 2019. A pilot study to compare virtual reality to hybrid simulation for opioid related overdose and naloxone training	To train and test virtual simulation with participants to find out character features and indications of Opioid-related overdose.	Quasi-experimental pretest-posttest	50 senior year BSN students.	VR: Insta360 Pro Spherical VR 360 camera Studying/training	VR simulation students show equal results compared to other groups.
15	Aydin & Özyazicioglu. 2019. Using a Virtual Reality Headset to Decrease Pain Felt During a Venipuncture Procedure in Children	To measure usage of VR effect during venipuncture procedure in children.	Controlled study	120 children 60 children in control group and 60 children in tested group	VR: goggles Clinical nursing	Study shows good diminishing of pain during venipuncture procedure in children aged 9 to 12. VR headsets can be implemented in such procedures afterwards.
16	Butt, et al. 2017. Using Game-Based Virtual Reality with Haptics for Skill Acquisition	To measure a difference of skills and experience gained during live practise and VR game-based learning.	Mixed method	20 students 10 in control group and 10 in VR group	VR: Oculus Rift + wearable haptics Study/Training	VR studies were well accepted by students. Such studies motivate students.

						VR studies can develop students' skills and mastery.
17	Koç Özkan & Polat. 2019. The Effect of Virtual Reality and Kaleidoscope on Pain and Anxiety Levels During Venipuncture in Children	To measure effect of pain perception during venepuncture procedure using VR.(AR)	A randomized controlled study.	46 children in VR goggle group 46 children in Kaleidoscope group 43 children in control group	VR: goggles Clinical nursing	VR goggles distraction techniques were efficient in lowering perception of pain and anxiety during venepuncture.
18	Samorson, et al. 2019. Teaching Airway Insertion Skills to Nursing Faculty and Students Using Virtual Reality: A Pilot Study	To examine whether educational intervention with a pilot contemporary immersive reality simulation builds knowledge and is feasible to implement among nursing students and faculty	Mixed study (survey sampling and quasi-experimental one group pretest-posttest)	1 group of 21 students	VR: Oculus Rift + Touch Virtual Reality Headset Bundle. Study/Training	VR education process improved the ability of students and other learners to achieve and obtain necessary results.
19	Gerçeker, et al. 2019. Effects of Virtual Reality and External Cold and Vibration on Pain in 7- to 12-Year-Old Children During Phlebotomy: A	To measure the impact of the VR and external cold and vibration methods on pain scores in children during phlebotomy.	Randomized controlled trial	147 children 121 children had phlebotomy procedure	VR: Samsung Gear Oculus headset Studying	VR can be used to prevent uncontrolled pain in patients.

	Randomized Controlled Trial					
20	Sahin & Basak. 2019. The Effects of Intraoperative Progressive Muscle Relaxation and Virtual Reality Application on Anxiety, Vital Signs, and Satisfaction: A Randomized Controlled Trial	To measure progressive muscle relaxation and application of virtual reality on anxiety, vital signs and satisfaction levels during a knee arthroscopy operation.	Randomized controlled trial	93 patients	VR: goggles Clinical nursing	Study shows little or no difference in reducing anxiety in the intraoperative period. VR was found to be effective in satisfactory level of the patients. VR usage is easy and cheap method to apply during surgery procedure.
21	Ferrandini, et al. 2018. Comparative study of a simulated incident with multiple victims and immersive virtual reality	To determine the efficiency of the START (Simple Triage and Rapid Treatment) triage, comparing to Virtual Reality (VR) to Clinical Simulation (CS) in a Mass Casualty Incident (MCI). To determine the stress produced in the health professionals in the two situations described.	Comparative/S tistical study	20 students as victims 35 students as volunteers of study.	VR: Samsung Gear Studying/training	VR was proven to be useful in START training The results indicated equal scores for success and errors in triage. Less stress in VR method.