A Survey of Possibilities and Challenges with AR/VR/MR and Gamification Usage in Healthcare

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Abstract: Software and applications of augmented reality (AR), virtual reality (VR), and mixed reality (MR) technology combined with game/gamification techniques in healthcare have increasingly been studied in academia. However, there is a need to explore the usage, challenges and opportunities of AR/VR/MR game/gamification software/applications in the healthcare system. To explore this, we present an online survey conducted in the healthcare-relevant system (including hospital-based system, homecare-based system, institute and university, and industry). Based on the answers, we found examples of digital games and AR/VR/MR applications used in healthcare, as well as some general information (name and feature, purpose, target user, and use occasion), usage situation, and user experience. This presented survey is beneficial for both researchers and developers in computer science and medical science. It can familiarise them with existing products and their current use, advantages and potential issues of AR/VR/MR and game applications in healthcare. In future work, the survey would be extended to obtain other user experiences and feedback of AR/VR/MR techniques and game/gamification technology applied to healthcare, as well as to study how to overcome the challenges, and develop the opportunities further.

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1 INTRODUCTION

Recent research has started to focus on combining augmented, virtual and mixed reality (AR/VR/MR) technology with game techniques in healthcare applications. These applications have been developed to match the requirements of healthcare issues or to enhance traditional solutions in healthcare. This paper presents a user survey with relevant staff, students, and professionals related to the healthcare area, with the aim to explore the possibilities and challenges with AR/VR/MR and game/gamification applied in healthcare. The research objectives focused on the use, opportunities, and challenges, with AR/VR/MR techniques and game/gamification technology.

The rest of the paper is organised as follows. Section 1.1 describes the relevant background concepts including VR/AR/MR and game/gamification. Then, Section 2 illustrates the related work in both medical science and computer science. Next, Section 3 explains the aim and objectives, research questions, and the research method, including the ethics description of this research, questionnaire structure and logic, questions topic content, and pilot study. Section 4 shows the result based on 30 questionnaire answers, including the perspective of application purpose and target user, use time and frequency, advantages and disadvantages, obstacles to mass adoption, and requirements and concerns. Based on the results presented in Section 4, Section 5 tries to explore the possible reasons behind the results. Finally, Section6 gives a summary of the study and highlights some relevant future work.

1.1 Background

Games are not a concept only in the field of computer science, but they are increasingly familiar and used in other areas because they are often combined with computer technology. A game is a system based on a rule, which has a variable and quantifiable outcome, with assigned different values (Lima et al., 2017). The effort of the player will influence the result (Lima

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et al., 2017). The challenge and fun in the game are the primary motivations for people to play it. Gamification is using game-design elements and principles in non-game contexts (Deterding et al., 2011), and it aims to bring the benefits of games to non-game contexts. AR systems add or remove virtual (computer-generated) objects, which coexist in the same space as the real world (Blusi, 2014). VR systems are different. They generate 3D objects by the computer, which simulates a virtual world, and cut off users' perception of the real world by using peripherals such as immersion glasses and interaction devices (Okeil, 2010). MR is sometimes referred to as 'hybrid reality', and is the merging of real worlds and virtual environments. MR provides new environments and visualisations, where physical and digital objects can coexist and interact in real-time (de Lima et al., 2016).

According to the immersion level, Li et al. classified AR/VR techniques into seven categories: (1) least-immersive VR, (2) semi-immersive VR, (3) immersive VR, (4) tangible AR, (5) collaborative AR, (6) distributed VR/AR, and (7) other VR/AR (Li et al., 2018). They claimed that technology selection leads to different immersion and interaction and should adapt to the application requirements (Li et al., 2018).

According to equipment, Okeil grouped VR by two immersive levels: (1) immersive VR (using HMD or CAVE) and (2) non-immersive VR (using screen including laptop, computer, mobile, tablet PC, TV, and large screen) (Okeil, 2010). Desktop-based VR was defined as operating on a simple computer monitor, controlled by mouse and keyboard, and without tracking equipment (Wang et al., 2018). Although desktop-based VR provided lower-level immersion, compared with other kinds of VR techniques, the device also has a lower cost. Immersive VR relies on specialised hardware such as HMDs and sensor gloves (Wang et al., 2018).

Adding sensors into the hardware made them provide real-time feedback. Because of the real-time capabilities, Sacks and Pikas believed that immersive VR is better than non-immersive VR (Sacks and Pikas, 2013). Additionally, Wang et al. highlight that by integrating visual and interactive multi-user operation technologies, VR training games could reduce the complexity of task processes, thereby enhancing user interactions (Wang et al., 2018).

2 RELATED WORK

Ma et al. summarised three keywords to the future trends of VR/AR and game in healthcare: the location-based exergaming, mobile apps, and social media gaming for public health (Ma et al., 2014). They claimed that the approach of healthcare and medical education might be changed by the research and development of mobile devices combined with wearable devices over the next decade (Ma et al., 2014). A social media effect on games in healthcare will be growing due to social games' popularity and social interactions' effectiveness (Ma et al., 2014). AR/VR techniques were proven effective to some healthcare issues, as a new solution or to enhance the conventional solutions. Jorge et al. reviewed the approaches and challenges to the VR/AR technique in healthcare and rehabilitation (Jorge et al., 2019). In the review, they illustrated several exciting VR/AR systems, such as VR for radiologists in the reading room, and in the operations room, augmented surgery, and laparoscopic, as well as exergames for locomotion rehabilitation by VR (Jorge et al., 2019).

Perkins Coie LLP and the XR Association have surveyed AR/VR yearly, since 2017. They interviewed 200 startup founders in 2019, executives with established technology companies, investors and consultants in the AR/VR/MR related area, in the past four years. In their new survey report in 2019 (LLP and the XR Association, 2019), they pointed out that 90% of the respondents believed immersive technologies including AR/VR/MR would be ubiquitous like mobile devices, by 2025.

They also claimed that the quality of user experiences, available content offerings, and the pace of adoption were the concerns and similar to the past surveys' result. For AR technology to be mass adopted, the largest obstacle was the lower user experience, including bulky hardware or technical glitches. The second one was the content offerings, including the quantity and quality of content. Similarly with the survey results of AR technology, user experience and offering content were the two most considerable obstacles to getting VR technology to be mass adopted. Respondents also pointed out that the most common concern was the slow adoption among consumers.

Some respondents believed hardware should be more user-friendly, and the cost, comfort and utility should be addressed. However, they have still strong confidence with them when it comes to the future of the AR/VR/MR technologies. One of the respondents said that immersive technologies could connect further to people in an organisation, such as in doctors' offices or schools, instead of only facing individual consumers. In their report, the game technique again, as in their previous surveys, led the combination with AR/VR/MR applications. Not far behind was the healthcare and medical devices.

Figure 1: Example of AR/VR/MR technology.

3 METHOD

The survey used an online questionnaire to evaluate the usage of AR/VR/MR applications and game/gamification technology in healthcare. The research questions are shown below:

- RQ1: How can digital game/gamification and AR/VR/MR technology be applied in healthcare?
- RQ2: What are the opportunities and challenges of game/gamification and AR/VR/MR applications in healthcare?

The link to the questionnaire was either emailed to target organisations, or posted on social media such as LinkedIn and Twitter. Based on the principles of Singer and Vinson's practical guideline for ethical issues on the conduct of empirical studies (Singer and Vinson, 2002), and the General Data Protection Regulation (GDPR) (Voigt and Von dem Bussche, 2017), we created a detailed ethics description of our survey in the informed consent, and illustrated it in the invitation letter, the consent form, and the beginning of the online questionnaire. Here it was highlighted that no sensitive data was gathered and it was all confidential.

In the questionnaire, there were three sections with 85 questions. Out of these, 17 were required and mandatory marked with a star. The structure and logic of the questionnaire are shown in Fig. 2, Except for the informed consent, the other questions included two aspects: (1) general information and (2) topic-related questions. Before the topic-related questions, there was an introduction to the survey, informed consent, background concepts introduced, and data collection of the respondents' general information (including the location, and occupation and the work content of the participant). In the topic-related questions, we tried to obtain information about the game/gamification application(s) and AR/VR/MR application(s) in healthcare. To address RQ1, the application(s) information questions

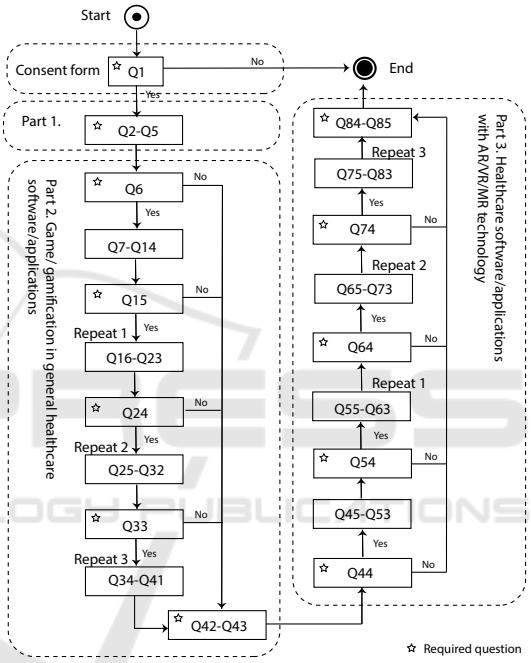

Figure 2: The questionnaire structure and logic.

(Game/gamification part: Q7-Q14; AR/VR/MR part: Q45 to Q53) covered application name and feature, purpose, target user, use environment, use frequency, use time, advantages and disadvantages, and whether it was using a game/gamification technique (only in Part 3). To answer RQ2, we generated questions (Game/gamification part: Q42-Q43; AR/VR/MR part: Q84-Q85) to better know the requirements and obstacles to mass adoption of AR/VR/MR techniques and game technology.

In part two and three, the questions for collecting application information were repeated three times (Game/gamification part: Q16-Q23, Q25-Q32, Q34-41; AR/VR/MR part: Q55-Q63, Q65-73, Q75-83), to obtain further data if the interviewee used more than one software/application. Before each repetition, there was a required question (Game/gamification

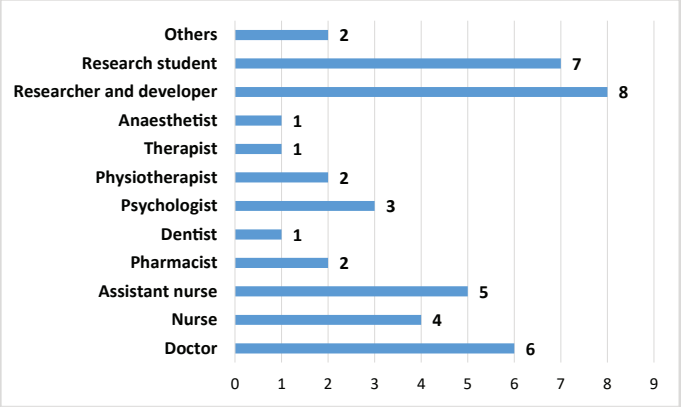

Figure 3: Participant's position.

part: Q15, Q24, Q33; AR/VR/MR part: Q54, Q64, Q74) to determine whether to enter the follow-up repeat questions at this stage or directly jump to the next section. If the respondents did not have the user experience of another software/application, they could skip these questions. There were instructions at the beginning of each part, and after the questions, to reduce any misunderstanding.

The questions were designed as a single choice, multiple-choice, and open questions. For the single-choice or multiple-choice questions, we quantified the options and performed descriptive tables to analyse them. Before the main questionnaire survey was carried out, five researchers from the internal organisation were invited to participate in a brief pilot study to estimate the answering time, test the validity of the questionnaire, and obtain any potential comments or feedback on the main questionnaire.

4 RESULTS

By mid-November (2020-11-15), there were 31 answers from ten countries (Sweden, Australia, China, USA, Netherlands, Thailand, the United Kingdom, Spain, Japan, and Germany). One answer was excluded due to the participant position being a babysitter (not necessarily related to the medical background requirement). In this work, healthcare-relevant knowledge and skill are not mandatory, despite useful. Hence, this was classified to belong to non-healthcare relevant work in the analysis. Thus, the following analysis and results were based on 30 individual participants.

The interviewees mainly came from academia (ten people), hospital (eight people), and primary health care organisations (six people). As shown in Fig. 3, the participants were working more as research students, researchers, and developers in their organisation. Their main tasks were research and studying in their fields, such as eHealth, information systems, telecommunication systems, palliative care, dental hygienists, psychological counselling, and nursing. Classification of the doctors and nurses in the participants were various, such as being an orthopedist, paediatrician, pharmacist, family doctor, as well as midwife, or in elderly home care.

From the 30 answers, we found six people having experience of game/gamification software/applications, and 16 people had experience with AR/VR/MR software/applications, which involved six games, and nine AR/VR/MR software/applications amongst them. Based on the used techniques, these software/applications were classified into three groups: (1) game/gamification (without AR/VR/MR), (2) game/gamification and AR/VR/MR, and (3) AR/VR/MR (non-game/gamification). Table 1 shows the general information (name and feature, purpose, target user, and use occasion) of the software/applications.

4.1 Application Purpose and Target User

Game/gamification and AR/VR/MR applications in healthcare were shown to aim to deal with a variety of health issues. Applications' purpose were classified as three groups with eight subgroups, for prevention (including disease prevention, health behaviour training/health knowledge teaching, and encouraging exercise), for treatment (including mental treatment, adjuvant therapy, physiotherapy and rehabilitation), and for medical education and training.

As shown in Table 1, there were 15 software/applications mentioned in the survey answers. The game/gamification techniques were mainly used

Table 1: The general information of the software/applications.

Name/feature	Purpose	User	Occasion
Game/gamification			
Digital patient meeting	Mental treatment, Disease prevention	Hospital-based care provider, Patient	Hospital
Null	Medical education and training, Health behaviour training/ Health knowledge teaching, Adjuvant therapy	Hospital-based care provider, Home-based care provider, Medical student	Hospital, Home, School/University/Institute, Outdoors
Treatment for autistic children	Mental treatment, Adjuvant therapy	Patient	Hospital
Word puzzle	Disease prevention	Patient, High-risk group of certain diseases	Home
HUAWEI health wrist ring	Health behaviour training/ Health knowledge teaching, Encouraging exercise	Hospital-based care provider, Home-based care provider	Hospital, Home, Outdoors, School/University/Institute
Game/gamification + AR/VR/MR			
"Deep"	Mental treatment, Health behaviour training/ Health knowledge teaching	High-risk group of certain diseases, Patient, Home-based care provider, Hospital-based care provider, Lecturer and Researcher, Patient	Hospital, Home, School/University/Institute
"Stress jam"	Mental treatment, Health behaviour training/ Health knowledge teaching	High-risk group of certain diseases, Patient	Home, Hospital
VR technique in simulation CPR	Medical education and training	Medical student	School/University/Institute
VR exercise game	Encouraging exercise, Health behaviour training/ Health knowledge teaching	High-risk group of certain diseases, Patient	Home
The model video of operation	Mental, treatment, Medical education and training, Health behaviour training/ Health knowledge teaching, Adjuvant therapy, Disease prevention	Home-based care provider, Hospital-based care provider, Lecturer and Researcher, Patient	Hospital, Home, School/University/Institute
AR/VR/MR			
For autism spectrum disorder treatment	Mental treatment	Patient	Hospital
3D body map, 3D human body anatomy	Medical education and training	Medical student	Home, Hospital, School/University/Institute
Training software for X-ray imaging	Medical education and training	Hospital-based care provider	Hospital, School/University/Institute
Virtual surgery, Surgical simulation	Medical education and training	Medical student	Hospital, School/University/Institute
"MindMaze" (stroke rehabilitation training)	Rehabilitation, Encouraging exercise	Hospital-based care provider, Home-based care provider, Patient	Home, Hospital

Note: The "Null" means the information was not mentioned in the participant's answer.

in mental health treatment, and health behaviour training/health knowledge teaching, especially combined with the AR/VR/MR technology. Those two kinds of software/applications purposes involved the treatment of mental health problems such as autism, stress ("Stressjam"), and anxiety ("Deep"); as well as physical training.

Except for being used in the mental health treatment and health behaviour training/health knowledge teaching, the AR/VR/MR techniques were widely used in medical education and training, such as in cardiopulmonary resuscitation (CPR), surgery, and 3D body map (for medical students to study the knowledge of human anatomy). It is worth noting that AR/VR/MR in medical education and training was commonly used without game/gamification techniques.

Based on the purpose and features, the primary target user of the software/applications were hospital-based care provider and patient. They were generally used in the hospital and home. Furthermore, the software/applications for medical students were mainly used in a school, university, or institute.

4.2 Use Time and Frequency

Just four participants mentioned the software/applications use time, and two refer to the frequency. There were four years for the HUAWEI health wrist ring used in the interviewee's organisation and two years for the Deep and Stressjam, as well as one year for the CPR simulation. The HUAWEI health wrist ring used in the interviewee's organisation was reported to be used two hours per week, and for Deep, it was about five hours. The other 27 participants claimed they did not know the use time and frequency of the software/applications in their organisations.

4.3 Advantages and Disadvantages

From the view of advantages in game/gamification software/applications, some participants believed they were helpful, such as the HUAWEI health wrist ring for users' health, as well as autism spectrum disorder (ASD) treatment software for ASD patients, their families, and doctors. Moreover, an interviewee said, "game is more in line with children's cognition and acceptance". Another person thought game applications provide stronger motivation than non-game activities. On the other hand, the interviewees mentioned the disadvantages of game/gamification techniques as well. One of them pointed out the cost of suitable equipment and software support being quite expensive. Two others said problems of game/gamification could be that they might not be appropriate and could be addictive.

From the view of advantages of AR/VR/MR techniques in healthcare software/applications, the participant who mentioned the application for the model video operation believed it is more precise, more useful for the end of the operation and to get a better result. Using a CPR simulation application, one interviewee claimed the application provided the ability to change the setting for the patient/student. Moreover, the user of the 3D body map said, it is intuitive, clear, and easier to perceive the spatial position and relationship of various organs, bone, and blood vessels than in books. Furthermore, interviewees mentioned the advantage of simulation surgery was beneficial for being able to repeat several times. For Deep, safety was mentioned, for VR exercise game, it was the better gaming experience, and for X-ray imaging training applications, it was also safe and infinitely repeatable. The disadvantages of AR/VR/MR techniques in healthcare software/applications mainly focused on high cost and equipment. Especially the high cost of costumers led by over-reliance on high-tech electronic equipment, as well as problems with fluency and low quality presented caused by data transmission delays.

4.4 Obstacles to Mass Adoption

As shown in Fig. 4, the largest obstacle of game/gamification techniques to mass adoption was the user experience (25), and the following three were the main challenges: content offering (18), the cost to consumers (12) and the financing and investment (12) were tied for third. The first two obstacles of the AR/VR/MR techniques to mass adoption were the same as the game/gamification techniques: user experience (25) and content offering (23). However, the following were different. For the AR/VR/MR techniques, the cost to consumers (18) was the third obstacle, and the financing and investment (17) and the consumer and business reluctance (17) were tied as the fourth obstacle.

4.5 Requirements and Concerns

From the 30 answers, there were ten requirements of game/gamification and AR/VR/MR techniques in healthcare, as shown in Table 2. The keywords can be separated into two groups, the aim, purpose, and target users. We can see the requirements of physical health issues, such as exercise, rehabilitation, and muscle relaxation. Furthermore, the requirements put more attention to psychological and mental health problems both in treatment and training. Moreover, medical education and training were also mentioned in the requirements. The target user was not only ordinary and patients; some interviewees pointed out, especially the requirements facing students, elderly, children, and babies. However, the interviewees also expressed concerns about the process of technology realisation. Someone believed it is difficult to commercialise. Another thought that AR/VR/MR techniques might be too high tech for their patient groups who are the elderly over 65 years old. Moreover, the clinical effect could be challenging to verify.

5 DISCUSSION

Although several interviewees coming from academia may cause many software/applications related to medical education and training, it was undeniable the numbers of mature software/applications used in healthcare. Students and researchers, as their primary target users, may lead to an easier acceptance of new techniques. The requirements of the medical education and training software/applications were more straightforward and clear to analyse, such as the 3D body map for studying the human body anatomy, and X-ray imaging training for learning how to take X-ray images. Thus, the design and prototype process of such software was more comfortable to implement and evaluate.

A safe, controlled, and a repeatable environment; multi-angle presentation; and simulation of the real world were the main reasons for the AR/VR/MR techniques used in healthcare. The AR/VR/MR techniques provided a virtual environment similar to the real world. It is a safe and controllable environment for expensive and high-risk teaching or training. Users can consolidate knowledge and skills in actual operations and avoid the serious consequences of incorrect operations. However, for serious purposes, the proportion of using games/gamification techniques in this kind of software/applications is relatively small. However, there is still space to combine game/gamification techniques into medical education and training software/applications.

Training skills in taking care of babies could look like a ”medical education and training” software, but for new parents instead of users with a medical background. It was mentioned both in the game/gamification and AR/VR/MR technique requirements in healthcare. In an environment that maintains social distancing and avoids gatherings for safety reasons, software/applications have become a better solution instead of face-to-face instruction.

The topic of treating psychological and mental health problems is an account for a large proportion

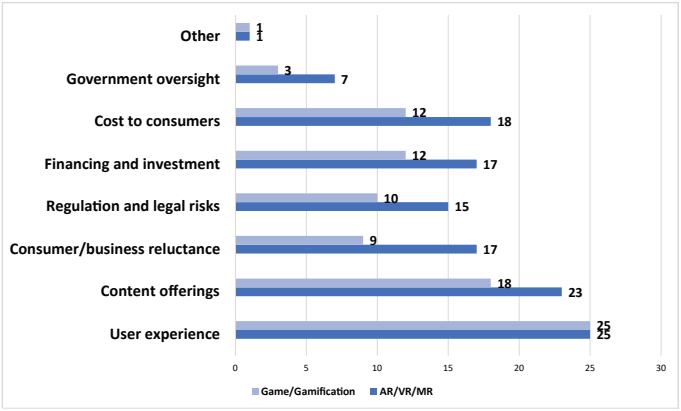

Figure 4: Obstacles to mass adoption of game/gamification and AR/VR/MR.

Table 2: Requirement of game/gamification and AR/VR/MR technique in healthcare software/applications.

Requirement	Game/ Gamification	AR/VR/MR
Prescribe exercise to clients	•	
Rehabilitation	•	•
Treatment of psychological and mental problems, such as phobia, PTSD, and dementia.	•	•
Game for the elderly health	•	•
Psychological diagnosis or psychotherapy, especially for the elderly and children.	•	•
Taking care skills training of baby	•	•
Memory training	•	
Mental relaxation and distraction	•	•
Teaching students		•
Muscle relaxation after prolonged sitting		•

of the overall, both in the results of existing software and the requirements designed. This theme has great demand and space for development. Similar to the medical education and training software/applications, the wide application of AR/VR/MR techniques in such software mainly lies in being safe and controllable. Virtual objects provide a safe and controllable treatment environment for doctors. They can influence the mental state of users through the tasks they are designed to provide treatment or relief, such as Deep and Stressjam. Games or gamification techniques could bring fun and motivation in the treatment, promoting usage time and effect. As mentioned by one interviewee, the gamification interaction was more friendly to children's cognitive level. In gamified tasks, they were easier to understand and accept in the software/application. This could also apply to users with cognitive impairments.

As the problem of population ageing on a global scale becomes increasingly serious, the health problems of the elderly are receiving more attention. This is also confirmed from the results of the requirements in healthcare. Many interviewees mentioned game/gamification and AR/VR/MR software/applications requirements for elderly healthcare.

Although the sample size of the total interviewees and each job position could be more extensive, the above results, show some usage and development trends of game/gamification and AR/VR/MR techniques in healthcare. Similar to the results in the related work, we can see the software/applications aimed at location-based exergaming and rehabilitation. It can also be seen that the AR/VR/MR techniques can be effective in some healthcare issues. On the other hand, the result of obstacles to mass adoption was similar to the related work as well. The user experience and content should be the most crucial quality indexes to consider. The usefulness of the software as the solution in healthcare and the acceptability of using AR/VR/MR were essential as well. Including medical experts and target users in the development and evaluation may help to solve this issue. Moreover, the customer cost (hardware and software) should balance with the user experience and effects.

6 CONCLUSIONS

This paper has presented an online survey, based on 30 participants, exploring the possibilities and challenges with AR/VR/MR and game/gamification usage in healthcare. The participants believed these techniques were helpful for some health issues due to the

acceptance and motivation in game/gamification; as well as the safety, repeatability, and potential for an improved experience in AR/VR/MR. However, the seen challenges were relating to cost and equipment. There were some requirements of game/gamification and AR/VR/MR in healthcare software/applications, such as in mental and psychological treatment, elderly health, and skills training in caretaking. The interviewees also pointed out the worries of the techniques and obstacles to mass adoption. Although the sample size was limited, a conclusion was still obtained, that game/gamification and AR/VR/MR have been accepted and applied in healthcare, as well as highlighting further development space of software and hardware. These insights are useful for both researchers and developers to know the state and development trends of game/gamification and AR/VR/MR in healthcare. Future work will extend the survey to a larger sample size, in several countries, to obtain more universal results.

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