User Experience of Mobile Virtual Reality: Experiment on Changes in Students' Attitudes

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ABSTRACT
Contemporary technological advancements, such as augmented reality and virtual reality, have extended smartphones' capabilities further than ever before. These devices are especially popular among students for performing their educational activities. However, students are skeptical or hesitant to try new technologies for various physical and psychological reasons, such as lack of knowledge, wrong attitudes, and misperceptions of the ease of installation and usage. In this study, we investigated students' mental models and perceptions of mobile virtual reality (MVR) application installation and usage. To achieve the research objective, we designed and developed an MVR case study application and conducted a usability evaluation, a user-experience assessment, and pre- and post-questionnaires. The questionnaires helped us compare the students' attitude changes from before and after the case study experiment. Based on the results of this study, we elaborate the challenges, opportunities, and best practices associated with the MVR application's design and development in an educational context. The results of this study will help practitioners design and develop robust MVR applications in an educational context and open up a new research domain for academicians on MVR design and development.

INTRODUCTION
The application design process and a brief evaluation of the case study were presented as a conference paper (Saballe, Le, & Dirin, 2018). In this paper, we present the opportunities, challenges, and best practices of a mobile virtual reality (MVR) application based on a case study evaluation. Advancements in mobile technologies have brought new opportunities for providing and offering new ways to teach and learn. Hallikainen, Alamäki, and Laukkanen (2018) demonstrated that people tend to use merely functional touchpoints, such as email, websites, search engines, and instant messaging. Motivating new users to try new technologies and acquiring new customers for new brands or technologies have been major concerns (e.g., Kaski, Alamäki, & Pullins, 2018). The lack of motivation to use new technology and acceptance of new technology are rooted in many factors, such as socioeconomic factors (Sife, Lwoga, & Sanga, 2007), psychological factors, including user perception (Davis, 1993), and emotional and cognitive factors (Huang, 2017).

Advancements in immersive technologies, such as MVR and mobile augmented reality (MAR), have shifted the concept of mobile learning into a new era. Virtual reality (VR) is not a new technology; it coexisted with desktop computers for many years. Steuer (1992) defined VR as a "presence and 'telepresence', which refers to the sense of being in an environment, generated by natural or mediated means, respectively" . VR has been applied in various disciplines, such personal computer- (PC) based VR applications for rehabilitating stroke patients (Jack et al., 2001) and applications of VR in motoric rehabilitation (Sveistrup, 2004). In recent years, VR has especially been applied in the neurosciences because it creates interactive, multimodal sensory stimuli that offer unique advantages over other approaches to neuroscientific research and applications (Bohil, Alicea, & Biocca, 2011). Additionally, VR technologies are applied widely in the tourism sector (Guttentag, 2010), for example, as entertainment media and in heritage preservation and marketing. Sánchez, María, & Maojo (2000) recommended a cognitive approach in designing VR systems for education. VR applications in education focus mainly on improving the learning process, for example, by creating a real-time welding training system (Xie, Zhou, & Yu, 2015) in constructional design and for building lighting (Sampaio, Ferreira, Rosário, & Martins, 2010). Further, VR has been applied to assess user experience (UX). For example, Kuliga, Thrash, Dalton, and Hölscher (2015) presented a multi-method VR model that constructed a virtual conference environment and used virtual environments as empirical research tools.

In MVR, we use our sensory inputs along with our sensory information processing in our brains to digest the flow of information (Virtual Reality Society, 2017). This unusual information flow through sensory inputs often results in so-called cyber sickness. Cyber sickness has similar symptoms to motion sickness, resulting in nausea, headaches, and dizziness (Rebenitsch & Owen, 2016). Besides physical symptoms, VR applications impact users' emotional behavior. VR glasses fully cover the eyes and field of vision; therefore, users lose awareness of their surroundings. This results in feelings of anxiety and stress. Therefore, VR application design requires careful planning to provide a positive experience for the application users. The rest of the paper is organized as follows. We start with an overview of the previous research on mobile UX and its relationship with MVR. Next, we present the research design, methods, and process and then describe our Virtual Campus Tour application design, which was used as a case study for this paper. In the results section, we present various evaluations of the case study. In the discussion section, we describe the challenges, opportunities, and best practices associated with the MVR UX.

Background

Defining Mobile User Experience

With the popularity of smart devices and applications' complexity of design and development, the role of UX has become an important element of mobile applications' success (Roto, Law, Vermeeren, & Hoonhout, 2010). It has become a viable supplement to traditional human–computer interaction (HCI) design, as indicated in practitioner discussions (Sakhardande & Thanawala, 2014). UX design is a multidimensional phenomenon in which many factors influence success. Mobile UX has been researched within various disciplines, such as graphics, psychology, and usability. These studies have demonstrated that UX by nature is a multidisciplinary concept. Hassenzahl (2008) referred to UX as the "quality of interactive technology" focusing on the human and not on the product. Furthermore, Hassenzahl and Tractinsky (2006) argued that with the advancement of technology, interactive products and services would become not only useful and usable but also trendy and fashionable. Nielsen and Norman (2015) defined UX as the simplicity of a product, accompanied by elegance, which users enjoy owning and using. In this study, UX was defined as the emotions that the user encounters while using a service, a product, or an application. Mobile UX design approaches often differ from web-based or PC-based applications because of unique mobile device features and characteristics, such as screen size or processing power.

Mobile Virtual Reality

Despite more than three decades of existence, the VR research still lacks a proper study from the UX perspective. The main focus of previous research has been on VR-based application development. Therefore, UX studies in VR in general and MVR specifically are vague and scattered. In the following, we elaborate few relevant UX-related VR studies. Rebelo et al. (2012) applied VR to assess user experience since VR provides a realistic virtual environment for the interaction. Shin (2018) demonstrated that personal traits correlate with immersion in VR and concluded that UX in VR depends on individual traits and the cognitive process, which impact how strongly users immerse themselves in the VR storyline. Various factors impact an individual's experiences in a virtual environment. For example, McCreery et al. (2013) identified the role of presence in virtual environments. They defined presence as "the psychological state where virtual experiences feel authentic". Therefore, presence impacts user behavior. Furthermore, individual experiences are constructed according to the user's emotional engagement and connection to the virtual environment and with the avatar (Dirin & Laine, 2018). Shin (2017) proposed a foundation of VR technology through heuristic evaluation based on the human cognitive process. Through this model, designers may validate and assess the utility of the design of a VR concept.

Virtual Reality Applications in the Educational Context

VR application as a research and development topic has existed in different research institutions for more than two decades. The unaffordable cost and psychological and physical inconvenience have impacted the use and popularity of VR in the educational context. In recent years, however, the advancement of this technology and the introduction of affordable peripheral devices, such as Google Cardboard (Yoo & Parker, 2015) have increased the popularity of VR. Olmos-Raya et al. (2018) studied the emotional and immersive effects of MVR in the learning process. Their findings highlighted a correlation between positive emotions and knowledge acquisition. Hussein and Nätterda (2015) investigated the benefits of VR application in comparison with a similar mobile application. Their findings revealed that students derive the most benefits from VR in astronomy and medicine (see also Davies, Crohn, & Treadgold, 2018) and also that VR is effective for performing tasks associated with safety. Similarly, VR provides an in-depth learning solution in situations requiring simulation and 3D printing. History and geography were also fields in which students could benefit tremendously from VR.

Changes in Attitude and Behavior

Bhattacherjee and Premkumar (2004) demonstrated that attitude and behavior directly impact perceptions of technological usage. Crano and Prislin (2011) argued that attitude changes occur in three different critical contexts. First, attitudes change because of values, goals, emotions, and human development. The second context is related to social relationships, including persuasive messages, culture, and social media. The third context is socio-historical, including socio-political changes, unique events, and economic impact. Petty (2012) defined attitude changes as a reshaping of an individual's overall evaluation of a person, object, or issue. Wilson, Lindsey, and Schooler (2000) demonstrated that changes in attitude override the previous attitude, but do not replace the old attitude. Hence, they argued for the presence of dual attitudes—that is, different evaluations of the same attitude object. Glasman and Albarracín (2006) demonstrated that there is a correlation between attitude changes and behavior. In their study, they examined how the formation of an attitude guides future behavior. Hannula (2002) suggested a conceptualization model for attitude based on four different aspects: emotions aroused in a situation, emotions associated with stimuli, expected consequences, and relating the situation to personal values. In his study, Hannula (2002) showed children's attitude changes toward mathematics over the time.

Research Design, Methodology, and Process
The following sections describe the research questions, participants, and methods used to evaluate the case study application.

Research Questions
1. How do attitudes change as a result of the experiment?
2. What are the major opportunities and challenges associated with MVR UX?

Participants
The case study evaluation was conducted in the media lab at the Haaga-Helia University of Applied Sciences in December of 2017. During the usability test, six participants (four females and two males, aged 18–30 years) who matched the user profiles were asked to spend 15 to 20 minutes using the application. The participants were recruited on a voluntary basis. No rewards were given for participation. All the collected data were anonymized so that the participants could not be identified from the results presented in this paper. Table 1 presents an overview of our test plan.

Table 1. Participants in the case study evaluation

Methods	Participants	N	Male	Females	Age (Average)
Usability evaluation	Haaga-Helia (4), other (2)	6	4	2	18–30 (25)
User experience	Haaga-Helia (4), other (2)	6	4	2	18–30 (25)
Questionnaire	Haaga-Helia (35)	35	22	8	18–33 (26)

Research Method: Case Study
- **Data Collection**

In this study, we applied both quantitative and qualitative data gathering and analysis methods.
We created a questionnaire to assess the students' mental models of, and attitude toward, our MVR application. The questionnaire consisted of 10 statements pertaining to the students' perceptions of MVR in the educational context. Further, we extended the questionnaire with statements associated with their feelings about MVR. A five-point scale was used with "Strongly disagree" as 1 and "Strongly agree" as 5. We received 35 responses by the given deadline. Among the participants, 66% were male and 34% were female. Most participants (77.14%) were between 20 and 30 years old, 17% were over 30, and less than 6% were below 20.

We also conducted additional controlled evaluations of UX with three test users and usability evaluations with six test users at the Haaga-Helia media lab. The three participants in the UX test included a male and two females between the ages of 20 and 30 with backgrounds in business information technology (BITe) and media engineering from Haaga-Helia University of Applied Sciences (UAS) and Metropolia UAS. These three participants were asked to spend 20 to 30 minutes using the application. During this time, they were asked to perform given tasks, samples of which are presented in Table 2, while thinking aloud (Concurrent Think Aloud method).

Table 2. Sample pre-defined tasks

Step	Action	Expected result	Pass/Fail	Time, other comments
1	Move from the first floor lobby to Riitta's room on the sixth floor.	User successfully reaches Riitta's room and is greeted by the campus tour guide.		
2	Move from Riitta's room to the library on the third floor	User successfully navigates to the library and is greeted by the campus tour guide.		

Additionally, to assess the test users' attitudes (like/dislike) toward the scenes, we created various scene transitions. We developed the application with varying types of scene transitions—most with a loading wheel and two scenes transitioned without a loading wheel.

For the usability evaluation, the test users were recruited from among the students (male and female) at Haaga-Helia (n = 4) and other UAS (n = 2) in the Helsinki area. Each test user was given a Samsung Gear VR or cardboard VR viewer with a smart phone already plugged into it. We did not have any prerequisites for the test users, but we provided test instructions on how to use the gear and cardboard VR. We installed our MVR application in the test phones, and the users could see the content through VR glasses. An internet connection was not necessary for the application to run. We also used a smart phone (iPhone 10) that recorded the elapsed time. Furthermore, we prepared in advance the testing case forms, semi-structured interview questions, and papers for noting the participants' comments.

During the usability test session, the test users were asked to spend 15 to 20 minutes using the application.
During this time, participants did the following:

1. Completed a user research questionnaire before the test
2. Performed the given tasks on the site while thinking aloud
3. Completed the same research questionnaire after the test
4. Answered questions about their overall attitudes and satisfaction through semi-structured interviews

The main purpose of the interview in the usability evaluation phase was to assess the users' perceptions of, and attitudes regarding, MVR during, before, and after they learned about our MVR application. Table 3 presents the sample of our test plan.

Table 3. Sample of our test plan

Facilitator	**Provides VR gear, smart phones, and the test instructions**
Pre-test	Briefing about the test process
Tasks	1. Go to Riitta's room on the sixth floor 2. Proceed to the library and be welcomed by the avatar 3. Go to the entrance to the lobby on the first floor
Data collection	Audio recording, written notes, short interview
Debriefing	About the hardware Application About users' emotions while using the application
Time management	
Introduction	5 minutes
Test tasks	10–15 minutes (UX) 5–10 minutes (usability)
Debriefing	5–10 minutes
Reporting	120 minutes
Total	15–30 minutes per user 1.5–3 hours for 6 users

During the test sessions, the test facilitator briefly introduced the MVR application prototype and the purpose of the user testing to the participants. Additionally, the facilitator provided the basic guidelines for using the gear, responded to participants' questions, assisted participants in conducting the test, and debriefed the users during the interview.

The observer followed the users' performance during the test and recorded the time elapsed in each test case. Further, the observer followed the users' language and facial expressions and took notes on the testers' actions and comments, procedural errors, and problems and assisted the facilitator in writing down the participants' answers during the interview.

At the end of each evaluation session, we conducted a semi-structured interview and asked the following questions: What is your overall impression of the application? How do you feel after trying the application? What do you like best about the application?

- **Data analysis**

To analyze the collected data, we applied usability evaluation metrics, such as time spent on performing the predefined tasks and the number of tasks performed in a given time, to measure the application's efficiency. The qualitative dataset comprised transcribed think-aloud videos, observations, and semi-structured interviews. We applied transcript coding (Gorden, 1998) to the semi-structured interviews. Additionally, we applied comparative usability evaluations (Molich & Dumas, 2008) to report the findings of the usability evaluations. We utilized SPSS (Pallant, 2011) and Excel to analyze the questionnaires.

- **Case Study Design**

The aim of our MVR application was to provide a virtual tour of the Pasila campus for those students who received admission to the BITe degree program for the fall 2018 semester at Haaga-Helia UAS. The application concept was initiated by conducting a feasibility study on the essential needs of potential users. A potential application prototype based on users' requirements was designed and developed. The MVR application enables users to navigate through the main areas, such as the information desk, library, computer rooms, classrooms, and cafeterias. The MVR application starts the tour in the main lobby on the first floor, proceeds to certain places on the third and sixth floors, then returns to the main gate on the first floor. Figure 1 presents the application prototype.

Figure 1. Prototype of the application

The MVR application was mainly developed by students as a project for which the results have been published (Saballe et al., 2018). They used Unity (version 2017.3.0p4), with scripts written using C# and some assets imported from Google VR SDK (for controlling the GVR Reticle). The 360-degree background images used in the application were taken using an Insta360ONE camera. These were then wrapped as background by rendering them as Skybox components. A skybox is a panoramic view rendered around the whole scene to give the impression of complex scenery at the horizon. The hotspots were implemented and animated using Unity's particle system. A particle system displays and moves small, simple images to simulate fluid, smoke, or light effects. Unity's Collaborate service was also used for the team's seamless workflow and collaboration. The application was built on the Android platform on Samsung S7 and Honor 8 devices with the import of Android SDK and JDK.

Results

User Experience and Usability Evaluation Results

The average time to execute the predefined tasks was three minutes. The task performance depended on the user's previous experience with the MVR application. Expert users executed the tasks faster than novice users. Table 4 presents the average execution time in seconds.

Table 4. Task execution in seconds

Task1	Task2	Task3	Total
61	50	49	160

The data analysis indicated that more than half (57.14%) of the test users reported feeling dizzy after trying out the MVR application. For example, Markku, 25, stated, "I feel dizzy and nauseous; I can still feel it in my stomach. I also noticed that my eyes feel a little bit weird." When probed about why users felt dizzy, they gave the following potential causes:

- "The ground (plane) is a bit skewed; maybe that messes with my sense of balance." Markku, 25
- "The background looks blurry." Li, 26
- "The screen appears to be too close to my eyes." Yuki, 29

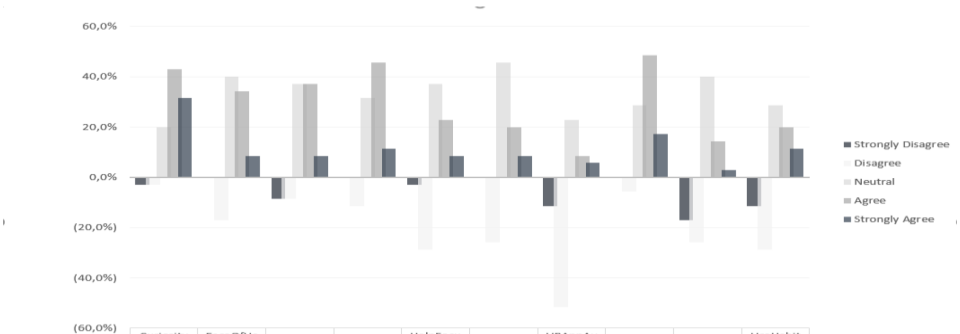
- "It takes some time to get used to the red dot (reticule). Sometimes I see the dots double, which feels uncomfortable, and I have to focus and concentrate on the dot all the time." Theo, 24

Three of the six participants who did not feel dizziness disclosed that they play online games.
The participants were asked about the time they would expect to spend on the MVR application. This question was asked before and after the experiment. Almost all test users (n = 15) anticipated spending 0–15 minutes on the application. One user expected the time to exceed 15 minutes. The scene loading time varied from 0.5 to 3 seconds. All participants preferred a loading wheel, and most of them preferred the loading time to be 1–2 seconds. For example, Victor, 23, stated, "I like the loading wheel because it gives me feedback and I have time to change my mind. It also prepares me mentally for the change of scene."

There were also some failures in the tasks: some users got lost due to the lack of instructions, signs, or maps to help with their current location and guide them where to go. Thus, they did not know how to proceed to the next location. Further, some elevator buttons did not work like the others, and the loading wheel disappeared from time to time, confusing them. In addition, the welcoming avatar was too big, according to Fung, 25: "I was overwhelmed by the picture; it was so big and covered the destination room so that I couldn't see anything else." Finally, wearing the head-mounted display device for a long time could eventually make some users' heads feel heavy. "This head-mounted VR gear would make me, and especially my head, feel heavy if I used it for a long time," said Mary, 22, who had played VR games before.

Questionnaire Results
To learn about the users' attitudes prior to and after the actual MVR application experiment, we asked the following question: *How do attitudes change as a result of the experiment*?

We endeavored to learn about the users' mental models of MVR applications as an educational tool. Figure 2 presents the participants' mental models of MVR applications. The figure displays the participants' general perceptions of MVR as a medium for educational purposes. It shows that about 75% positively answered that they were curious to try an MVR application in their educational activities. However, only about 31% perceived that they would use an MVR habitually for their studies. Additionally, 65.7% of participants agreed or strongly agreed that they had heard good things about MVR applications, and 57.1% positively perceived MVR as an engaging medium. However, less than one third of participants perceived MVR as an effective medium for studying. Only about 31% agreed or strongly agreed that MVR applications would help them focus on what they were studying. More than 63% of participants did not agree that there were currently many MVR applications for learning in the market. Figure 2 presents the students' perceptions of MVR.



	CuriosityToTry	EaseOfUse	Useful	Engaging	HelpFocus	Effective	VRAppAvailability	Positive	Negative	UseHabitually
Strongly Disagree	(2,9%)		(8,6%)		(2,9%)		(11,4%)		(17,1%)	(11,4%)
Disagree	(2,9%)	(17,1%)	(8,6%)	(11,4%)	(28,6%)	(25,7%)	(51,4%)	(5,7%)	(25,7%)	(28,6%)
Neutral	20,0%	40,0%	37,1%	31,4%	37,1%	45,7%	22,9%	28,6%	40,0%	28,6%
Agree	42,9%	34,3%	37,1%	45,7%	22,9%	20,0%	8,6%	48,6%	14,3%	20,0%
Strongly Agree	31,4%	8,6%	8,6%	11,4%	8,6%	8,6%	5,7%	17,1%	2,9%	11,4%

Figure 2. Students' perceptions of MVR

The post-questionnaire analysis demonstrated a change in the participants' perceptions of MVR mainly in four statements: "MVR applications are easy to use"; "I will use MVR apps habitually for my studies in the future"; "MVR is an effective medium for studying"; and "MVR is an engaging medium for studying." Figure 3 presents the percentages of agreement/disagreement among these factors.

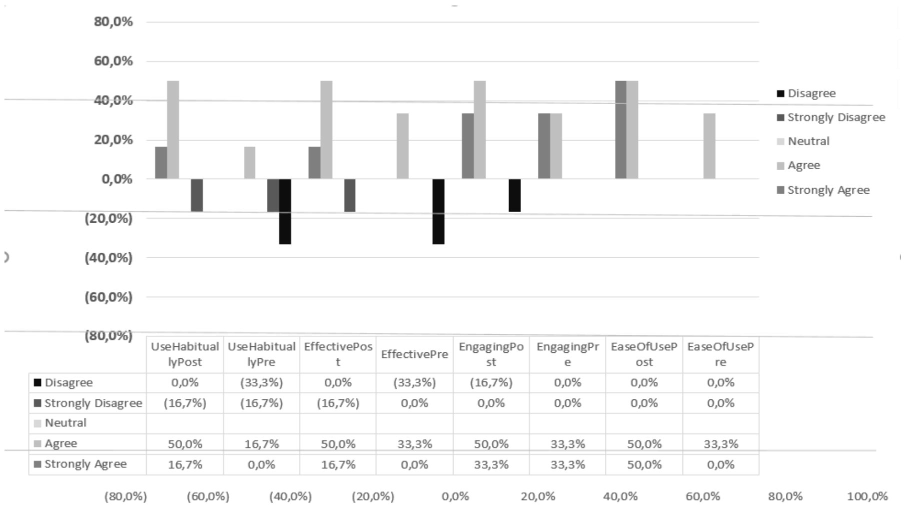


Figure 3. Students' perceptions of VR as an educational medium – pre- vs post-test

Among the testers, the perception that MVR applications are easy to use changed from 33% agreement to 100% agreement. Agreement that participants would use MVR applications habitually for studying also increased considerably from 17% to 67%. Agreement on the effectiveness of MVR as a medium for studying also increased from 33% to 66%. Lastly, the perception of MVR applications as an engaging medium for studying increased from 67% to 83% positive agreement. Figure 4 presents the users' pre- versus post-test feelings about the MVR application.

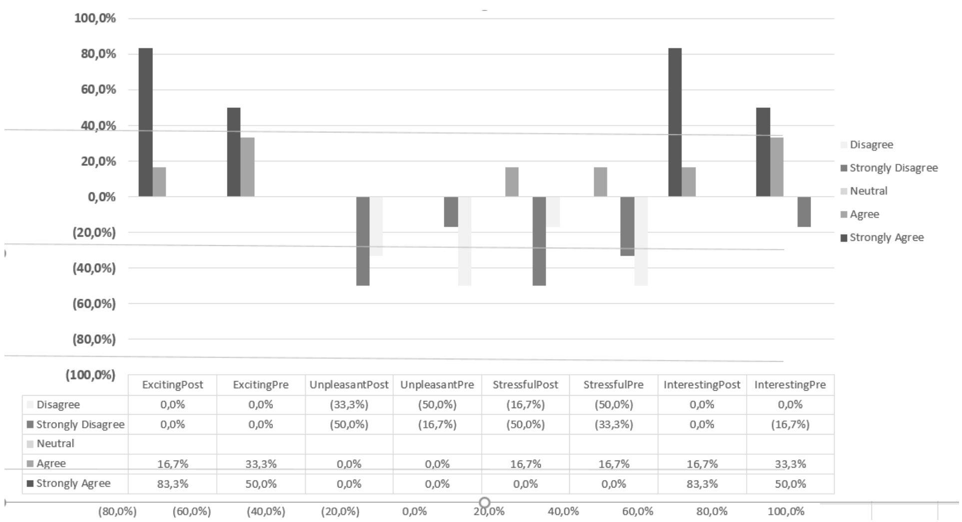


Figure 4. Students' feelings about MVR – pre- vs post-test

Changes in feelings about MVR as an educational medium were noted in four factors: *interesting*, *exciting*, *stressful*, and *unpleasant*, as presented in Figure 4. Both the statements "I feel that MVR apps are interesting" and "I feel that MVR applications are exciting" with 83% of participants strongly agreeing with statements in the post-questionnaire. Those who disagreed that MVR applications are unpleasant changed from 67% to 83%. However, those who disagreed that MVR applications are stressful changed from 83% to 67%, which suggests that some participants felt stressed during the tests.

Challenges, Opportunities, and Best Practices for Mobile Virtual Reality User Experience

MAR and MVR are gaining momentum among students. Therefore, the UX designs of applications of these technologies are becoming vital. The author has already published an article on MAR UX in the *Journal of Computers* (Dirin & Laine, 2018); to align with those findings on MVR UX, the next sections apply the same style as in the previous article.

Challenges of Mobile Virtual Reality User Experience

The main challenges identified during the case study experiment are summarized in Table 5.

Table 5. Main challenges associated with MVR UX

Challenges	Description
Physical	While using the MVR application, the user needs to completely focus on the application. The whole body needs to be involved: eyes focused only on the application, hands ready for possible interaction with the application through the control panel. It is impossible to perform any other task while using the MVR application.
Mental	New MVR applications often require that the user installs them first and then uses them through glasses. Installing new and possibly unknown applications requires extra effort and trust from users. Another mental challenge is the cognitive load caused by the bridging of the virtual and real worlds via rich multimedia contents. Moreover, the new ways of gathering and processing information can be mentally exhausting.
Prototyping	Technologies for supporting MVR application design and early prototyping are still in an early phase despite recent development.
Technical	There are still many technical challenges associated with MVR design and development. Technical immaturities, such as battery drain, required processing power (i.e., how to make it available on low-end devices), glasses, and screen size, can impact MVR application UX. From the perspectives of students, these technical deviances are UX drawbacks to using the MVR application in the long term.
User interface	Designers have already managed to construct user interface and interaction metaphors for non-AR mobile applications. Not all mobile application design metaphors are necessarily applicable to MVR applications; hence, new interface and interaction metaphors specific to MVR applications are needed.
Development	To develop a robust MVR application, application developers must utilize multiple integrated development environments. For example, in our case study, we worked with Unity 3D, C#, Android SDK and JDK, and Google VR SDK.
UX design	The mind-set change from mobile application to MVR concept design is associated with some challenges. Designers are required to adjust their design approaches, which are based on 2D sketching of non-VR objects using a pen and paper or mock-up tools, toward sketching 3D scenes and objects, which are viewed from a 2D perspective (i.e., the camera). Connected to this, as mentioned above, MVR UX designers lack robust prototyping tools to create prototypes for MVR objects and interaction.
Timing	The experiment demonstrated that participants got frustrated if MVR objects took up too much of their time, especially considering that the application's purpose is to entertain the user. The optimal presentation time needs to be carefully assigned depending on the context and the target user group.
Psychological and physical impacts	The unawareness of personal surroundings while using the MVR application resulted in stress and anxiety for users. These psychological impacts can cause users not to use the MVR for long periods. Furthermore, the experiment demonstrated that users became dizzy after using the application. However, this was only for the first few tries; then the brain adapted to the new information gathering and processing.

Opportunities for Mobile Virtual Reality User Experience

The main opportunities associated with MVR UX are presented in Table 6.

Table 6. Main opportunities associated with MVR UX

Opportunity	Description
Marketing potential	MVR creates a unique opportunity for practitioners to promote products and services. MVR can be applied in product advertisements, product training, and the exploration of various aspects of a product. MVR helps users perceive the product better. Further, it helps users become involved more closely with the product features and performance. MVR enables users to construct an emotional engagement with the product. Traditionally, the achievement of this type of emotional engagement with tangible products has been feasible through video advertisements. MVR can enable this emotional engagement through richer, multi-directional interactions (e.g., eyes, ears, hands).
Emotional engagement	Emotional engagement is the key result that MVR can bring to the user. Emotional engagement was also demonstrated in this study. After the experiment, the users' attitudes toward the MVR application changed (e.g., perceiving MVR as fun).
User interface	MVR provides alternative options to create novel user interfaces. Voice commands and virtual and handheld MVR object controls are examples of novel user interface components that can be associated with MVR applications.
Interaction	VR enables unique interaction experiences for mobile applications that previously were not feasible, such as voice commands, natural communication with an avatar, and rich visualization of the user interface, instead of using text-only labels and 2D graphics to guide the user.
Experience development	MVR enables designers to create context-sensitive illusions that ease the cognitive process for complex teaching, such as teaching welding to beginners by developing a complex 3D model, which enables the user to learn the welding process.

Best Practices for Mobile Augmented Reality User Experience Design

The best practices and a sample example based on our case study experiment are presented in Table 7.

Table 7. Details of best practices based on MVR UX design

Best practice	Description	Examples
Spatial correspondence	MVR object dimensions and locations should match the real-world object dimensions.	In our case study, the MVR panel dimensions and locations were situated in the exact places that the users expected. In our example, we aimed to construct a mental model of the real environment for our new students.
Tolerance of movement	MVR objects should be tolerant of movement.	In our case study, novice users experienced cyber nausea. Therefore, the objects' designs must be planned and organized properly.
Object detail	The details of MVR objects should be sufficiently precise (within the limits of the target hardware) to make them recognizable and appealing.	The avatar in our case study was a 3D cartoon object, which occupied the screen properly. We designed a zooming circle to help the user identify an object with finer details.
Object correspondence	Establishing correspondence between an MVR object and a real-world object creates a metaphorical link that increases familiarity and might lower the learning curve.	The avatar in our case study had high resemblance to Riitta, the academic advisor at BITe, Haaga-Helia.
Natural interaction	Allowing users to interact with MVR content via multiple natural methods (e.g., speech, touch, gestures) promotes realism.	The interaction in our case study was based on zooming in on an object's user interface and hard controls.
Personalized experience	Making the MVR experience personal to each user increases the likelihood of emotional	Our case study provided a one-size-fits-all experience to all users. Participants

	engagement. This can be done, for example, by allowing the user to customize the application or by automatically adapting the application to the user's context and preferences.	were unable to change preferences or otherwise customize the content.
Emotion-evoking avatar	It is recommended to include an avatar in MVR applications to make the interaction with the application more natural. Moreover, the avatar should have emotion-evoking properties, such as a pleasing appearance and body language that signals how the avatar feels.	The Riitta avatar in our case study was found to be appealing and was able to evoke emotions among the participants.

DISCUSSION
The latest technological advancements in MVR and affordable peripheral devices, such as VR glasses and remote controls, have allowed MVR to become an alternative medium to support educational offerings (Hussein & Nätterdal, 2015). Therefore, MVR applications are expected to arise increasingly in the educational context. In this study, we assessed how students perceive MVR and investigated whether their attitudes changed after they experienced the new technology. We developed a simple MVR application for first-year students in the BITe department. The aim of the MVR application was to familiarize them with the university campus, classrooms, library, and key staff. Through the case study application, we pursued answers to the initial research questions. We applied various methods to determine the users' perceptions and attitudes toward the MVR application, such as conducting a usability evaluation, interviews, and pre- and post-questionnaires. The usability evaluation helped us learn about the application's performance, effectiveness, and efficiency as well as user satisfaction (Riihiaho, 2017). Through the semi-structured interview, we learned the students' expectations for potential MVR application functionalities and performance. Livesey (2010) recommended using a semi-structured interview that allows participants to express their opinions on a specific subject. Furthermore, Livesey revealed that the objective of the semi-structured interview is to learn participants' viewpoints on a specific issue rather than identifying general behavior. A semi-structured interview is often conducted with a focus group. Longhurst (2010) recommended 6 to 12 participants who represent the target users. Additionally, the questionnaires provided information for measuring how perceptions changed after the MVR experiments.

The test users (n = 6) were able to perform all the predefined tasks in 4–6 minutes. They did not encounter any special obstructions or challenges with the tasks or the application performance. However, almost all the test users felt dizziness or nausea. Other researchers have identified this problem (e.g., Rebenitsch & Owen, 2016; Sharples, Cobb, Moody, & Wilson, 2008). Cyber sickness is common among novice users, which the designers may reduce or even overcome through proper background design approaches, such as color, movement of the background picture, short application periods (10 minutes), and decreasing the range of view, as Fernandes and Feiner (2016) recommended. Furthermore, providing visual feedback on the application's execution and processing (e.g., loading the application) helped users be involved and engage with the application and avoid frustration. The loading time affected users' frustration level significantly, as they were unaware of their surroundings due to the glasses and dark screen. We did not measure the optimal loading time, but users showed satisfaction with 0.5–3 seconds for each interaction in our case study. This time range depended on the individual user's previous experience with MVR. Advanced users showed more tolerance for loading the application than novice users. The questionnaire analyses indicated that the students' perceptions significantly changed after the experiment (Figure 3). This is understandable and aligns with the findings of Aarts and Dijksterhuis (2000), who found that goals and actions change habit and behavior.

1. *What is your overall impression of the MVR application?*

Prior to the experiment, most students (74.3%) agreed or strongly agreed that they were curious to try the MVR application. This aligns with *Forbes*' statistics, which show that people are increasingly using VR for social engagement (Koetsier, 2018) . The students' curiosity may have come from the fact that they would prefer to utilize mobile devices more and more for their educational activities (Dirin, Nieminen, & Kettunen, 2013). Among all the students who answered the questionnaire, 40.0% were neutral and 42.9% agreed or strongly agreed that the MVR application would not be easy to use. This indicates that even ICT students felt that they may have difficulties in using MVR. Despite this, some students (34%) thought the MVR application would be challenging but not boring (75%) and were curious (42.9%) to try the MVR application. Furthermore, our results indicate that the majority of students (66.7%) thought that the MVR application would be positive and effective in an educational context. Similarly, Özgen, Afacan, and Sürer (2019) showed that in an educational context, students prefer a VR conceptual design to a paper-based one despite the challenges associated with VR design. Table 8 presents the participants' attitudes toward the MVR application before and after usage.

Table 8. Users' attitudes toward the MVR application before and after the experiment

	Prior to experiment	**After the experiment**	**Variations**	**Comments**
Ease of use	Only 30.3% agreed that MVR would be easy to use.	Of the participants, 100% agreed or strongly agreed that the MVR application was easy to use.	Agreement that MVR was easy to use increased by 69.7%.	The MVR application experiment changed participants' perceptions of the ease of use of the MVR application.
Engaging	Of the participants, 66% agreed or strongly agreed that MVR would be engaging.	Of the participants, 88.3% agreed or strongly agreed that the MVR application was engaging.	Agreement that MVR was engaging increased by 18.3%.	The MVR experiment changed participants' perceptions of MVR engagement.
Effective	Of the participants, 33.3% strongly disagreed that MVR would be effective.	Of the participants, 16.7% strongly disagreed that the MVR application was effective.	Disbelief in the effectiveness of MVR decreased by 16.6%.	The MVR experiment had a positive impact on participants' attitudes toward MVR's effectiveness.
Use habitually	Of the participants, 50% strongly disagreed or agreed that they would use MVR habitually.	Of the participants, 16.7% strongly disagreed that they would use the MVR application habitually.	Attitudes toward the habitual use of MVR changed by 33.3%.	The experiment showed significant improvement in users' attitudes toward the potential use of the MVR application.

2. *How do you feel about MVR application?*

Our experiment revealed that despite initial doubt, the majority of participants would like to incorporate MVR in their learning process. Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2014) similarly showed that VR is an efficient learning instrument for students and yields positive outcomes for students (Lau & Lee, 2015). For example, our questionnaire results revealed that the majority (82%) of our participants agreed or strongly agreed that the MVR application is an interesting technology to be utilized in educational offerings. Furthermore, 79.9% considered the MVR application as fun to use. Similarly, Von Mammen, Knote, and Edenhofer (2016) demonstrated that despite the cyber sickness associated with VR, users nevertheless had fun using the VR application. Table 9 presents the users' attitude changes toward MVR application use.

Table 9. *Attitudes toward the MVR application from an emotional perspective*

	Prior to experiment	**After the experiment**	**Variations**	**Comments**
Interesting	Of the participants, 80% agreed or strongly agreed that MVR would be interesting.	Of the participants, 100% agreed or strongly agreed that the MVR application was interesting.	Agreement that MVR was interesting increased by 20%.	The MVR application experiment changed participants' perceptions.
Stressful	Of the participants, 33% strongly disagreed that MVR would be stressful.	Of the participants, 50.0% strongly disagreed that the MVR application was stressful.	Disagreement that MVR was stressful increased by 17%.	The MVR experiment changed participants' perceptions.
Unpleasant	Of the participants, 16.7% strongly disagreed that MVR would be unpleasant.	Of the participants, 50.0% strongly disagreed that the MVR application was unpleasant.	Disagreement that MVR was unpleasant increased by 34.7%.	The MVR experiment had a positive impact on participants' attitudes.
Exciting	Of the participants, 50% strongly agreed that MVR would be exciting.	Of the participants, 80.3% strongly agreed that the MVR application was exciting.	Agreement that MVR was exciting increased by 30.3%.	The experiment results showed significant improvement in users' attitudes toward the MVR application.

The results are accurate and valid in the context for which the application was designed, developed, and assessed. The main limitation of this study was the length of the MVR application. We may obtain different results in the case of a lengthier application. The gathered data provide an overview of students' perceptions and general attitudes toward MVR at the time of the study. Due to these limitations, we cannot generalize the results. Hence, the results are only valid in the context of this study and for the segment that this target group represents.

CONCLUSIONS

The study demonstrated a change in students' perceptions of new technology through a simple experiment. Our study also revealed that the majority of students are unaware of MVR applications in an educational context. Despite the improvements in smart device capabilities, such as memory, processing power, and affordability of cardboard glasses, students still have the wrong perception of MVR application installation and usage. Additionally, the results of this study reveal that novice users experienced more cyber sickness than experienced users. This is already a known issue and has been tackled in various studies. Therefore, we recommend special attention to MVR application design and development, such as selecting the proper colors for objects, movement of objects, and time to present the concept. We recommend 10–15 minutes as the optimal time for each chapter of the MVR application. The main limitations of this study were the number of test tasks and the VR application. The number of test tasks could have been greater to test the learners' attitudes for a longer period. The application, however, was designed and developed for students at the university on the basis of their needs. Therefore, the results regarding the application are valid, but the findings cannot be generalized.

As future work, we aim to design and develop new VR applications in an educational context and recruit more test users to generalize our results.

ACKNOWLEDGEMENTS

Special thanks to Charlese Saballe and Hang Le for designing the case study and conducting the usability evaluation.

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