Tampere University

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AN EXPERIMENT ON THE EFFECT OF AUGMENTED REALITY ON USER EXPERIENCE IN DIGITIZED SHOPPING

Information Technology

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ABSTRACT

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Augmented Reality (AR) technology has been defined as one of the major technologies likely to change the future of shopping. There has been much surmise about the potential of AR technology in the digitized shopping, however, very few empirical studies about its usability. This thesis describes an experiment that the user experience of AR information in a shopping task.

40 students came to the simulated second-hand LP record shops. In the traditional shopping, the LP records listed on the shelf with printed additional information. And in the AR shopping environment, instead of the printed paper, HoloLens is used to present the additional information. 20 students shopped in the traditional environment and the other 20 students were shopping in the AR environment. Each student spent 10 minutes shopping and after that they were asked to fill a mental workload survey. The traditional shopping environment was compared with the AR shopping environment.

Results indicate that with the AR technology, mental workload is higher, higher physical and temporal are required, however, gender difference influence and immersive tendency difference influence are not existing.

Keywords: Augmented reality, user experience, digitized shopping,

PREFACE

I would like to express my gratitude to my supervisor Juho Hamari and advisor Nannan Xi, who provided a lot of valuable guides, opinions, and suggestions to this thesis.

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Finally, I want to express my love and thanks to my parents for their unconditional support, without them I would not be who I am today.

Tampere, 04, November 2019

Shuo Yang

CONTENTS

LIST OF SYMBOLS AND ABBREVIATIONS

AR	Augmented Reality
VR	Virtual Reality
AI	Artificial Intelligence
UX	User Experience
3D	Three-dimensional
HCI	Human-Computer Interaction
HMD	Head Mounted Display
HUD	Head Up Displays
MANOVA	Multivariate Analysis of Variance
ANOVA	Analysis of Variance

1. INTRODUCTION

Shopping is an indispensable customer activity in our daily lives. The popularity and development of the internet has made e-commerce into a burgeoning business, we are currently at the phase of rapid growth of so-called “internet economy”. The rapid growth of e-commerce has not been without reasons: the advantages in saving time and money, abundant information about a certain product in terms of selecting a suitable one, etc.

In traditional shopping environment, customers can see, touch and feel the quality of a product directly. Additionally, customers can get a product as soon as they have paid, which can provide customers a high sense of security, especially when they are shopping for expensive items such as jewelries and large electronics.

Online shopping is not geographically confined to a certain location, making it possible for customers to shop without going out of their homes, which in turn leads to higher efficiency and cost-saving. Moreover, in the era of the internet, we easily compare, e.g. price, product types, etc., before making a decision to buy or not.

The main drawbacks with traditional retailing are that the market is already very competitive, and that the profits are dwindling. We live in a society where efficiency plays an essential role, more and more people prefer online shopping to traditional way of shopping. Due to the above reasons, real economy might fall into a recession.

However, the current online shopping is not perfect either. For instance, the main format of online shopping is some “lifeless” pictorial information, which is untouchable and imperceptible. Not being able to see the use case and real quality of the product, customers tend to offline purchase the kinds of high-valued large items, such as furniture.

Many retailers believe that Augmented Reality (AR) can provide an effective solution for the existing problems in offline shopping context, thus making it a promising technology for offline shopping.

The emerging AR e-commerce has proven its value to market leaders (Digi-Capital, 2017). AR e-commerce has huge sales potential in consumer electronics, furniture, health/personal care, toys, food, and media. According to the report from Digi-Capital (2017), AR e-commerce’s yearly revenue is expected to increase to $ 60 billion and attracting over 1 billion users by 2021. The revenue source of Mobile AR will be more from non-game industry, e-commerce is ranked second, comes on the heels of mobile network data service.

The 2016 Retail Perceptions Report indicates that 40% of the customers are more willing to buy the product if they can experience it through AR; 61% of the customers prefer to shop at stores that provide AR, and 71% of the customers like to come to shop more often if AR is available in the retailer (Retail Perceptions Report, 2016).

Because of the limitations of the Virtual Reality (VR) technology and device, increasingly many companies are resorting to the AR technology. Many famous brands, e.g. IKEA and Amazon, have launched IKEA Place (IKEA, 2017) and Amazon View (Amazon, accessed 2019), respectively. The combination of AR and retail has clearly drawn wide attention. As part of effort for enhancing user experience of Buy+ mobile VR, Alibaba published AR Buy+ (Carlton, 2018). Korean telephone company KT Corp launched an AR mobile shopping service, AR Market (KT Corp, 2018), to provide customers a better shopping experience in order to make up for the gaps between online and offline shopping. FaceCake, a self-claimed pioneer in interactive marketing, released Dangle (FaceCake, 2018), the first AR shopping APP for jewelry. Dangle solves the biggest digital shopping challenges for earrings: actual size, shape, color and how they fit the user's personal style. Dangle combined AR and Artificial Intelligence (AI) technology, depending on customers personal features, Dangle will recommend suitable earrings for them, while users can virtually try on earrings in real-time as if they were looking in a mirror at the shop. Furthermore, in the US payments and financial technology summit Money 20/20, a prototype proposed by Masterpass, ODG, and Qualcomm (thefintechtimes, 2017), has attracted a lot of attention.

An often-used metric for measuring user experience is mental workload, it plays a very important role in the Human-Computer Interaction (HCI) field. It is necessary to control the mental workload and job enrichment to realize job satisfaction (Cook and Salvendy, 1999). The mental workload of users when they use the product also directly influences the user subjective satisfaction. There are three primary technologies have been considered to change the shopping method in the near future, AR technology is one of them. AR can serve as a tool to provide accurate information in a direct way to users through the shopping process. It seems obvious that AR support eases the shopping process and increases the shopping efficiency of the user. However, the acceptance of new technology and its additional information can also potentially increase the user's workload. Gender difference also will affect the user experience of augmented reality technology, the research result shows that males are more receptive to AR technology than females (Suh & Prophet, 2018). The immersive tendency will have a magnificent impact on the user experience of AR as well, which is usually positive, and generally people with high immersive tendency have relatively high user experience in AR (Witmer & Singer, 1998).

The results of the study of Zhao et, al. (2017) indicate that the mental workload in the AR shopping of males is significantly higher than that of females. Furthermore, among males the mental workload of products with high values was considerably higher than that of low-valued products.

Although some studies have begun to explore the marketing value of mixed reality technologies, scholars in the field of information systems focus on how computer and interface technology can be enhanced to improve human interaction, while others in the marketing research field narrowly and unsystematically investigate psychological experiences in entertainment, e-commerce, and tourism. In other words, meaningful research that crosses the border between marketing and computer science is yet to emerge. Especially in the retail context, there is still a dearth of empirical studies examining how to use AR technology to positively influence the user experience.

More importantly, only a few studies have investigated the experiential value of AR technology by designing laboratory experiments in simulated conditions, such as an online shopping website, a shopping app, a virtual fitting room, etc. However, the deep-seated mechanism of mixed reality technologies' effects on user experience is still unknown.

There are six dimensions of mental workload, which are mental demand, physical demand, temporal demand, performance, effort and frustration level. These are the primary elements that affects the quality and the result of AR shopping. Thence, it is of great significance to study the mental workload of AR shopping.

To fill out the research gap, which is mentioned above, the general objective is to investigate a key question in both current and future digital marketing – how mixed reality technologies affect user experience. To achieve this general objective, this study will focus on the following two specific levels:

RQ1：What are the differences in workload between non-augmented reality shopping environment and augmented reality shopping environment?

RQ2：How much a) gender and b) immersive tendency moderate the effect of AR on shopping workload?

As described above, the combination of mixed reality technology and shopping has been used a lot in the last couple of years, however, there is a lack of comparing the effect augmented reality on user experience in digitized shopping. Therefore, this thesis we are going to do two groups of experiment which are real shop environment and augmented shop environment through comparison and analysis to support whether AR technology will influence user experience in digital shopping and what kind of influence it will be.

However, as developers focus on the immersion aspect of AR technology, the importance of interaction design has been neglected. The present interaction design has been effective for Web and Mobile applications, almost everyone has a lot of excellent interactive design products on their smart devices. As a direct factor that influences the user experience, interaction design should be added into the AR researches, to enable the AR technology more fully realize the interaction between human and products.

This thesis belongs to User Experience (UX), which is dedicated to designing users a series of systems that are able to provide a superior experience. The main purpose of this thesis is to compare different shopping experience on the Real shop and AR shop two platforms, to understand user experience and to give suggestions for future study.

2. AUGMENTED REALITY

Augmented Reality (AR) is a parallel technology based on Virtual Reality technology. In 1994, Milgram and Kishino et al. presented the model of mixed reality (Milgram and Kishino, 1994). In 1977, Ronald Azuma put forward augmented reality should include the following content (Azuma, 1997):

“Combines real and virtual: Real-world and virtual objects should be in the same visual space”.

“Interactive in real times: User can naturally interactive in real-time with the real world and virtual objects”.

“Registered in 3D: The position of the computer camera and sitting can make the virtual object are able to be put in the correct position in the space”.

Using computers to generate virtual images to overlap with the real physical world, according to the sensor to let the user immerse into the virtual world to achieve the sense experience what more than physical reality, so that users can have natural interaction with the environment directly (Huffington Post, 2016). The general AR devices in our lives are two forms which are handheld devices and wearable devices. Handheld devices are mainly mobile hardware, like the smartphone (Azuma et al., 2001; Tenmoku et al., 2003; Van Krevelen and Poelman, 2007, 2010). And the wearable devices are mainly headset display, such as HoloLens published by Microsoft and Google Glass. With the maturity of mobile devices and related technology, AR has been incorporated into a lot of areas of our lives, by scanning the book, the virtual content will appear on the paper (Bilinghurst and Duenser, 2012); according to body recognition algorithm and motion-capture, customers can do virtual fitting in the store on just online (Carmigniani et al., 2011). Besides, AR applications are also used in the military, medical, machine manufacturing, indoor decoration, mobile navigation, advertising, and many other fields. In addition, augmented reality technology does not require much development funds, and the requirement of vehicle equipment are also relatively low, especially it has shown a huge potential value on smartphone platforms. In recent years, AR emerged because of the applications on mobile devices based on the IOS and Android platform, Apple also added support of AR technology - ARKit into their smart devices, in the operating system level advance AR technology development (Olsson et al., 2009). For users, mobile AR technology is more convenient, the cost of user experience is relatively low, fit user habits and more widely accessible.

AR technology has been considered to have many potentials in the shopping area and there are already some merchants have published very mature AR shopping applications to the public (Simonetti Ibañez & Paredes Figueras, 2013).

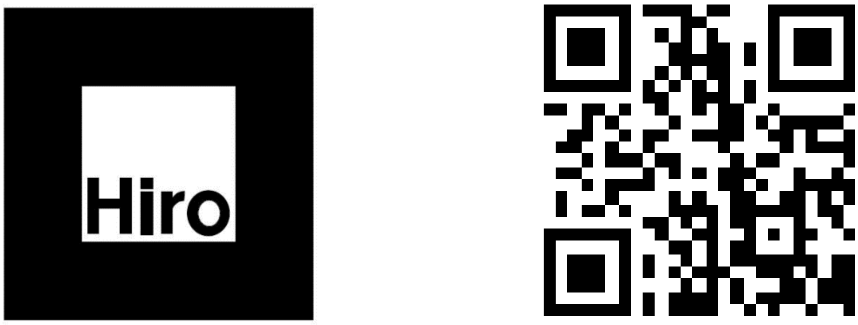
2.1 Marker-based AR and Markerless AR

Augmented reality is to put the real world and digital information that created by computer into camera view of user's devices, enhancing real world by using digital information, but not introduce real environment information in the virtual world (Kim and Hyun, 2016; Azuma, 1993). Augmented reality is a revolutionary technology, what could let users can naturally interact with the real physical world (Mackay, 1998), changed how the information is displayed, make the world to be the user interface (Wellner et al., 1993).

There are three features of augmented reality which are the combination of the actual and virtual conditions, real-time interaction and three-dimensional registration. And these features are mainly relying on personal computer, head-mounted display, GPS mobile devices, etc., external equipment to implement the system (Livingston et al., 2013).

The category of augmented reality is not unchanged all the time, it will change as the development of AR technology. Through the content of the evolutionary process of concept, the main category of augmented reality can be analyzed. Based on whether the marker is used, AR can be classified into two categories, these two categories have been called marker-based augmented reality and markerless augmented reality. From the categorization method, it is possible to find that marker-based augmented reality is the main category, as it can define the other category as markerless augmented reality.

In the most extensive meaning, AR marker (ARToolkit, 2005) is a picture or the presentation of real-world objects, it can provide a special mode that is able to be captured by the AR camera and recognized by the AR program. The form of the marker can be relatively obvious, such as QR Code, and also can be relatively converted such as images of scenery and even human face (Fiala, 2005). After the augmented reality program recognizes the marker, the program will calculate a relatively exact location, and then import a related virtual object, make the virtual object appear near the real environment marker in real-time (Figure 1).



a) ARToolKit Marker *b) QR Code*

Figure 1. *Marker example*

The proposed concept of the marker is the starting point of augmented reality definition. it used to define markerless AR, which is not marker-based, the opposite category of AR. Marker-based AR has been widely applied in all types of AR in the past long time. However, as the development of the augmented reality, as a marker category, human face has been widely used, makes it is not very suitable to use marker to define and describe the category. Thus, it is a good idea to use a word which is able to apply in the whole augmented reality area to replace marker. From QR Code to human face, the concept of marker is not what they are in common, as it is not suitable to use human face as marker. As image recognition is the common ground between them, thus, the word "Recognition-based AR" is the most suitable for the expression. (Starner et al., 1997, Comport et al., 2006).

Marker-based AR technology use marker as a reference point to define the position, direction, and size of augmented reality object in the real world. If the object is a three-dimensional model, users will be able to observe it in overall view by 360 degrees rotation mark objects. Marker is not a modality of augmented reality but an important part of a particular kind of AR technology. Besides, the core part of AR is not object tracking but how to blend virtual objects into the real environment.

The essence of markerless AR is that not to use any special marker to track objects in the real world. Facial recognition is a good example, in the strict sense, facial recognition is not belonging to markerless AR. Even though there are differences between human face and traditional augmented reality printed markers in some ways, functionally, human face works similarly to other markers. It can be said as a type of high precision and high complexity. The human face is a natural marker but is still a marker functionally.

As a simple example to clearly explain the above concept. If there are some life-size human face pictures, users use smart devices to search AR object, to match the human face with pictures. If the work status of the facial recognition program is good enough, it is possible to see a unanimous result. It seems like there are processed two marker-based AR examples. For AR applications, human face and images are the same types of marker, the program can recognize them only because the digital image of the human face has been saved into the database with the other type of markers, just like the printed image marker. In other words, it is possible to classify the following three types of AR markers: digital marker (such as images on the computer screen), printed marker (like magazine pictures) and nature marker (like human face) (Azuma, 1997).

The difference between location based AR and recognition based AR is, in practical use, if user cover the camera, in recognition based AR, the virtual object disappears from the screen, but in location based AR, the virtual object is continue to exist on the screen, will not be influenced by the change of the real environment.

There are two major types of AR technology, location based AR is one of them. It can integrate the computer-generated virtual object into the real world. This method is not based on vision marker. It built from the location of AR objects in the physical world. In these two conditions, AR objects can tighten even seamless integration with the physical objects, but with the essentially different between two AR types, there are different effects when extract and analyze the camera image. In the recognition-based AR (i.e. marker-based AR) situation, AR object is able to disappear but location-based AR (i.e. markless AR) do not disappear. However, this problem can be solved by programming, for example, hidden the AR object when the camera input is undetectable. As the further development of technology, marker-based augmented reality has been developed into recognition based augmented reality, and markerless augmented reality has been developed into location-based augmented reality (Reitmayr and Schmalstieg, 2003; Paucher and Turk, 2010).

To reduce the AR software development complexity, several research organizations published some kits that are able to handle low-level tasks, in these kits, including the basic functions such as pattern recognition, coordinate transformation and video merge.

In the augmented reality shop, we used the method of Image Target, with this method, users are possible to create recognize image by their own, and detect the recognize image and based on the recognize image to render a custom 3D object, i.e., add the virtual information to the target image in the real world and apply it on the smart device. It is possible to use multi-database in Vuforia and each database contains 100 targets.

2.2 Application areas of augmented reality

There are already a lot of potential applications with AR technology, involving engineering design, entertainment, industrial training and retail.

As we know the Head Mounted Display (HMD) is used in military area in the beginning, helped military personnel to know the complex topography and dynamic environment, Applied Research Associates(ARA) has published ARC4, a military smart glasses, which could help soldiers to master the conditions and situations on the war (Applied research associates(ARA).); Israel has developed an augmented reality software can provide terrain model and intelligence data to commander, thus occupy the best positions to monitoring all situations (Furht, 2011). In the medical area, doctors import the probes or the endoscope into patines, through the augmented reality technology it is possible to export the visual image of the visceral organs, then the surgeon can gain the information and match with the internal structure of the human body, to reduce the operating difficulty (Danciu et al., 2011). AR technology can be used in the industrial equipment to visual display the equipment failure, maintenance instructions, accurate guide the technician how to remove and installing the certain part, saving time and cost to some extent, improve the work efficiency (Rüßmann et al., 2015). Wikitude (Wikitude.2008) , Layar Reality (Brent W. Hopkins, 2010) , etc. browser application can provide information and interesting point for the environment where user views; AR cards and AR books application is suitable for children education, after scan the card or book to enter into the AR view mode, children can enhance the knowledge of things through the combination of the plane figure and solid image (Bacca et al., 2014). With the popularization of the portable computer and smart device, the augmented reality technology applied on mobile terminal becomes very popular, augmented reality game Pokémon Go (Pokémon go.2016) received with a lot of users' approval, opening up a new path for the augmented reality game development. As mobile communication equipment is convenient to carry, the cost of user experience is low. Thus, AR technology has been widely used in the consumption area.

In order to offer users better shopping experience, traditional retailers fully utilize the technology to upgrade the experience of their service. As the developing of AR technology, the increasing numbers of retail industry introduced this technology and creates various service applications. Japanese cosmetic company Shiseido has developed a Magic Mirror, it is a makeup simulation. Users are possible to experience different makeup looks in real time (Shiseido's magic mirror.2011). Germany shoe company

Goertaz let customers are possible to do virtual fitting by using Microsoft Kinect technology and upload the pictures to Facebook and the QR code shown on the screen leading to the checkout (Goertz: The augmented reality shoe store.2012). Glasses online retail company Warby Parker has developed an augmented reality application which can measure pupillary distance, and also possible to let users try different frames online (Warby parker's AR app.2019). One of the biggest American chain drugstore Walgreens, large occupation area, a wide variety of medicines, for the convenience to the users, Walgreens use augmented reality technology to set an augmented reality map onto the shopping cart to guide customers to the location of the product they required, and the error range is only several inches, when the customer find their required product, the related discount information and coupons will automatically pop up (Michelle Saettler, 2017). Through all these practical applies to AR, the use of AR technology was from the usual exhibition gradually extended to the experience of personalized services.

3. USER EXPERIENCE

3.1 The overview of user experience

In the 90s, Don Norman identified the word “user experience”, declaring that “User experience encompasses all aspects of the end user's interaction with the company, its services, and its products.” User experience influence all the things interact with the product, it surpasses HCI and emphasized the aspect of humanization. User experience depends on the product using context, the environment of the product using is changing as time goes by, user experience involves a large context that able to understand users operate, and to find out the role of the product in their lives. Also, user experience is changing with time, user’s experience to the product is dynamic. For instance, when users first time get smartphones, they may feel confusing how to use it, as they do not have any context to expect. But later, when users get familiar with the smartphone and depend on the value of the smartphone, their experience will be more and more positive, because they become emotionally attached (Norman, 2013).

The father of “Ajax”, Jesse James Garrett mentioned in his “The elements of user experience”(Garrett, 2010) that there are five panels in user experience, these five panels are similar to the process when designing the daily life product, following the order surface panel, skeleton panel, structure panel, scope panel, and strategy panel.

The surface panel means that the design needs to meet the visual requirements of users, using the visual flow to guide users operate. The skeleton panel means that to organize the information structure, optimizing the design layout, set product and each element has interaction with users reasonably, facilitate the users to switch in different modules. The structure panel refers to that describe the internal logic relationship of product, arrange the content elements make the scope panel more specific. And then the scope panel means that need to comb the product content requirements and function combinations. At last, the strategy panel refers to that focus on the user requirements, decide the strategic goal and the goal we want to achieve through the product.

The following figure 2 is the model of the elements of user experience, it clearly shows the five panels of user experience and all user experience elements involved in each panel.

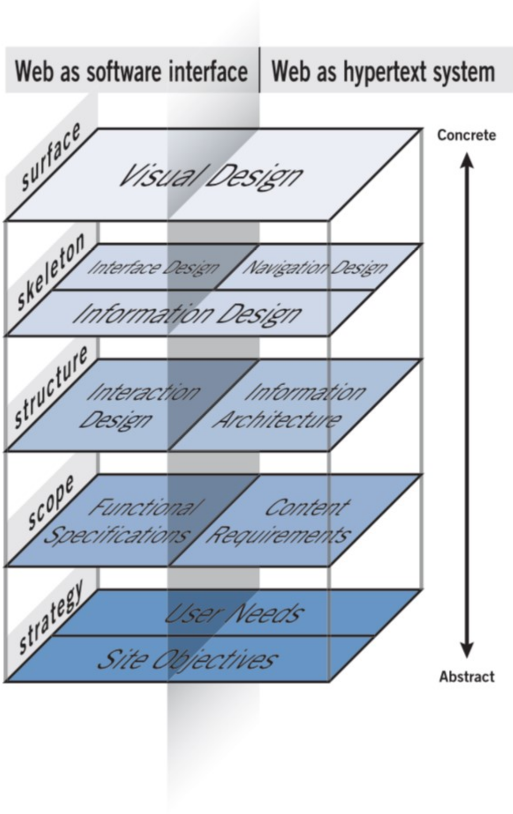


Figure 2. *Elements of user experience model (Garrett, 2010)*

The product user experience should be built from the bottom, and then meet the users' emotional needs step by step, this has quite resemblance to Maslow's hierarchy of needs (McLeod, 2007). The theory of Maslow's hierarchy of needs is from the most basic physiological needs and safety needs to emotion belonging and self-actualization, corresponding to the product user experience is that first, we need to meet the user's most basic functional requirement and the usability of the product, let the users feel it is easy to use; then it steps up to emotional level, makes user have pleasure and positive feeling, thereby make user dependence on the product; the last level is also the highest level, which is self-actualization, users find their own interest, belong, and value through the product, let the product to become a self-mapping.

Donald·A·Norman in "Emotional Design" has divided the external feedback and the cognition of the brain into three levels which are visceral, behavioral and reflective from the angle of human's brain work (Norman, 2004). These three levels are the laws of the brain working, map to the design, it also worthy of following and explore.

There are many research methods in the user experience area, some methods are verified by a wide range of examples, and some methods are new methods appearing with constant development. Christian Rohrer classified these methods into three dimensions. The first dimension is user attitude and user behavior. (Rohrer, 2014)

In this dimension mainly discusses “what user said” and “what user do”, and to do the comparative research on these two. Some companies marketing department using the investigation related to user attitude, the purpose is to have a better understanding of users’ opinion and perspective.

Although usability research is more dependent on user behavior research, there are a lot of advantages by using the method of self-described to get to know user attitude. For instance, card sorting can help with deciding the best information on product, application, or the information architecture of the website. Survey can be used to generalize user attitude, help to track or discovery the important problem that needs to solve. In the other aspect of this dimension, “what user do” focuses on user behavior in product or service are discussed. Such as A/B testing present the changes in the design of the site randomly to users, in the situation of remain the other constants, to get users behavior choices about the first version and the second version of the user interface design, and eye tracking is possible to help with understanding the user and visual interface interaction. Besides, usability studies and field studies, not only can comprehend user self-described viewpoint, but also possible to get their behavioral data.

The difference between qualitative research and quantitative research is that qualitative research gains the corresponding data directly through observation or interview, while quantitative research is to obtain data indirectly by using the data collection tool. Qualitative research normally has nothing to do with mathematics, need to reach the research goal through designing interview questions, observe user behavior, generally can adopt research methods such as field research, usability research, open-ended questions, etc. Quantitative research usually requires accurate statistics and analysis, need to compile and calculate the research questionnaire or the data collected from server logs.

Due to the basic differences between qualitative and quantitative research, qualitative research is more suitable to answer the question “why and how fixe”, however, quantitative research is more suited to answer the research question such as “how many and how much”.

3.2 Workload

User experience is determined by many factors, but for different types of products that include different user groups, using purpose and usage scenario, etc., the evaluation dimensions and the weights between are vary. There are various definitions of Mental

Workload, in general, it is able to think of mental load as physical load, the physical effort to complete an operation, which means the mental effort and psychological pressure required to perform or complete a task.

At present, there are two kinds of assessment methods that are widely used, which are Subjective Workload Assessment Technology, SWAT for short and National Aeronautics and Space Administration-Task Load Index, NASA-TLX for short. SWAT metrics system includes Time Load, Effort Load, and Psychological Stress Load, three metrics. NASA-TLX is a subjective workload assessment tool, the main purpose is to evaluate the subjective workload of the operators of various human-computer interface. By adopting a multi-dimensional rating process, NASA-TLX scores the overall mental workload based on the ratings of six dimensions' weighted average. NASA-TLX is one of the most proverbially applicable mental workload scales with the best validity, not only the user acceptability is high, but also the variation between the subjects is minimal and its simple structure is also very suitable for daily user research. NASA-TLX evaluates the overall mental workload from six dimensions of mental demand, physical demand, temporal demand, performance, effort, and frustration level. NASA-TLX has been in development for nearly 20 years, Sandra.G.Hart (2006) has made a report for its use status, the data show that most of the implementation areas of NASA-TLX are in the interface design: visual or auditory displays takes 31% and audio or manual input devices takes 11%.

Both NASA-TLX and SWAT are subjective reporting, based on respondents' own feeling, and analysis the workload from multiple dimensions. Firstly, to analyse the importance of the source of workload, to determine the weight of each dimension, next, to score each factor index, and finally, to calculate the comprehensive workload index according to the scores and weights of each index. The difference is that the SWAT and NASA-TLX analysis have different dimensions. Compare to NASA-TLX, which has six dimensions, SWAT, which has only three dimensions shows the lack and deficiencies, while it also makes SWAT easier to implement and less time-consuming. Thus, SWAT is suitable to analyse the cognitive requirements or allocation of attention resources required for a particular task, and NASA-TLX is appropriate when the goal is to predict how a particular individual will perform on a particular task (Rubio, Díaz, Martín, & Puente, 2004; Byers, Bittner Jr, Hill, Zaklad, & Christ, 1988; Tsang & Velazquez, 1996; Hart & Wickens, 1990; Hart, 2006).

4. USER EXPERIENCE AND AUGMENTED REALITY

In essence, shopping is an experiencing activity. Shopping experience means that through the sense organs, tactile organs and thinking activity, the feeling and experience that people gain in the shopping environment and process (Falk & Campbell, 1997). In the digital shopping design, augmented reality extends the virtual information image into the real space and virtual reality is to make a virtual environment as same as the real one and added to the virtual information image on the basis of it. The nature HCI of augmented reality technology also strengthened the interactivity between customer and shopping environment, made customers can gain information satisfaction in a very efficient way in the real environment. There are a lot of limitations because of various reasons such as the size of the product, language, etc. in traditional shopping, customers are not possible to get the expected information. However, through the augmented reality technology, customers are possible to gain the virtual visual information on the augmented reality while getting visual and sensory information in the real environment, for example, because of the size limitation of the product, not all information can be presented on it, or in offline shopping, customers can not see the other people's comments for the product, whereas augmented technology can fill the information lack, in order to make customers to gain the information satisfaction. AR can satisfy users' sense of experience and make users feel the simulated transactions of the virtual world in the real world. In this way, it not only enhanced the interest of users but also guarantees the interactivity between users and technology. Moreover, in the social aspect, AR does not separate users with the real world but focuses on the interaction with people around, including eye contact and expression. Users are possible to test products, watch product information and call friends to ask their opinions while seeing the real environment ((Apple Inc., 2017; Cooper, Reimann, & Cronin, 2007; Nielsen, 1995).

User experience (UX) design for AR products, the first step is to "augment" information in the real world, actually, the information is not limited to the text, but also includes pictures, 3D objects, sounds, etc. the existence forms include virtual information and real-world information. Next, human cognition has continuity, in the process of evolution from one stage to another, there is always a "middle ground", in this process, continuity and inheritance should be established between the two stages to help users to build a "mental model" of new things. Therefore, for the AR UX design, existing interaction rules and design specifications, such as feedback of controls and gestures should be more consistent in the basic interaction level.

The comparison diagram of WIMP is shown below, including four basic points in UX design: window, icon, menu, and pointers. By comparing PC, smartphone and AR, differences and continuations of interaction on different platforms can be seen.

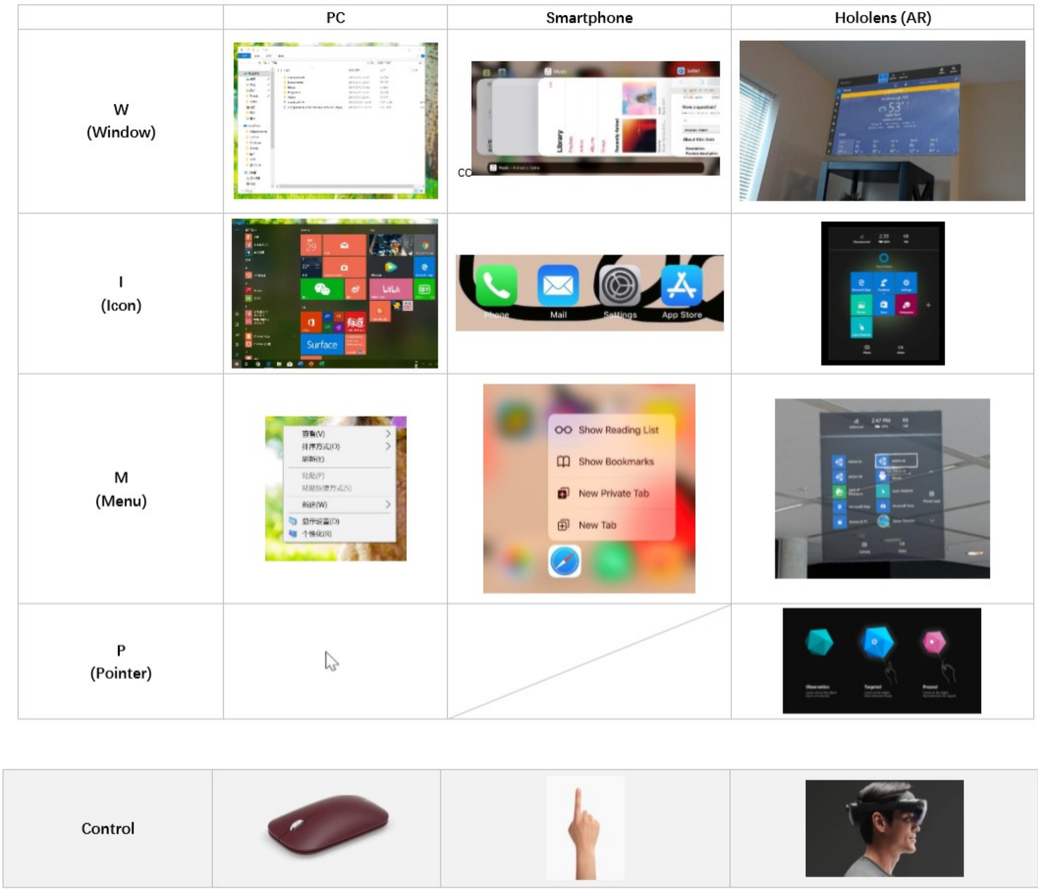


Figure 3. *Comparison of WIMP in PC, smartphone and AR*

The consistency of user experience within the system and application should be concerned, that the same information, function, and operation should be consistent. This consistency includes consistent structure, consistent color, consistent operation, consistent feedback, and consistent text (Nielsen, 1995).

Thirdly, user-centered design. Users are the controller of the product, and the design should always revolve around users. All objects, including the environment, should be able to control the state and give natural feedback, some scenes should be metaphorical and explorable as well. Since AR products are closer to the real world, the appropriate use of the metaphors will make the interacting objects more "real". The reasonable use of metaphor not only implies the proper use method but also avoids restrictions (Berfin Ayhan, 2017; Apple inc. iOS11 human interface guidelines-augmented reality, 2017; Tyler Wilson, 2017; Neil Mathew, 2017).

4.1 Gender and immersive tendency

A systematic literature review was conducted by Suh and Prophet (2018) of studies that the state of immersive technology, and presented two findings about the gender difference in immersive technology use which are males are disposed to accept AR technologies than females, besides, in the immersive environment, females are easier to got motion sickness than males while using head mounted displays.

There are series of experiments (Munafo et al.,2017; Lin, 2017) to show that compare to males, females are tend to feel motion sickness; the motion sickness caused by the head-mounted display, the feeling is strong for females than males, further supported the idea of in the illuminated environment, women are more easily tend to motion sickness because of the linear oscillation (Koslucher et al. 2015), likewise, corroborated the ideas of Lawther and Griffin (1986 & 1988), who suggested that generally, women are more easily tend to motion sickness.

In 1998, Witmer and Singer performed immersive tendency questionnaire and presence questionnaire to show that immersive tendency have positive relationship with presence i.e. a person who got high score in immersive tendency questionnaire, have a higher chance to be immersed in the virtual world, and should also have higher score on the presence questionnaire, which means when they interact with the virtual world, they will be feeling more presence.

Jerome and Witmer (2002) identified the system effectiveness training influence the personal tendency to immersing into the simulation. Identified presence as the system effectiveness affect the cognitive feeling of existing in the virtual environment. However, Jerome and Witmer found that the relationship between presence and the immersive tendency is small and nonsignificant positive. They reported because of the simulator sickness as the moderator, there could be mediating relationship among immersive tendency and presence as well. Considering that immersive tendency increased sickness symptoms, and presence reduced because of the sickness symptoms, this may be the mediate reason that influences the positive relationship of them.

Additionally, in 2004, Jerome and Witmer published in which they described there might be an indirect relationship existing among the immersive tendency and virtual environment performance, and via presence can fully mediating it. The immersive tendency might be not easily manipulated as it is a typical feature of individual.

4.2 Research object/content and Research Framework

There are two steps in the S-O model which are stimulus and organism. These two steps are used to outline how is people's reaction to stimuli in the environment. This thesis uses the S-O framework to explain how mixed reality technology influences the user experience in the retail context.

Based on whether the real environment or augmented environment, here we have two experiment conditions, reality shop and augmented reality shop as an independent variable. And the real shop as the control condition, the other as the experimental conditions.

According to the literature review, studies have shown that user's cognitive and emotional reactions are influenced by immersive features, and then result in user performance (Merchant et al., 2014; Suh & Prophet, 2018). Hence, the framework presumes that the augmented reality (stimuli) have an influence on the user experience (organisms) which is the workload. There is considerable literature shows that individual differences which are immersive tendency and gender have moderating effect between augmented reality and user experience (Arino et al., 2014; Hou et al., 2012; Lin, 2017; Munafo et al., 2017; Shin & Biocca, 2018).

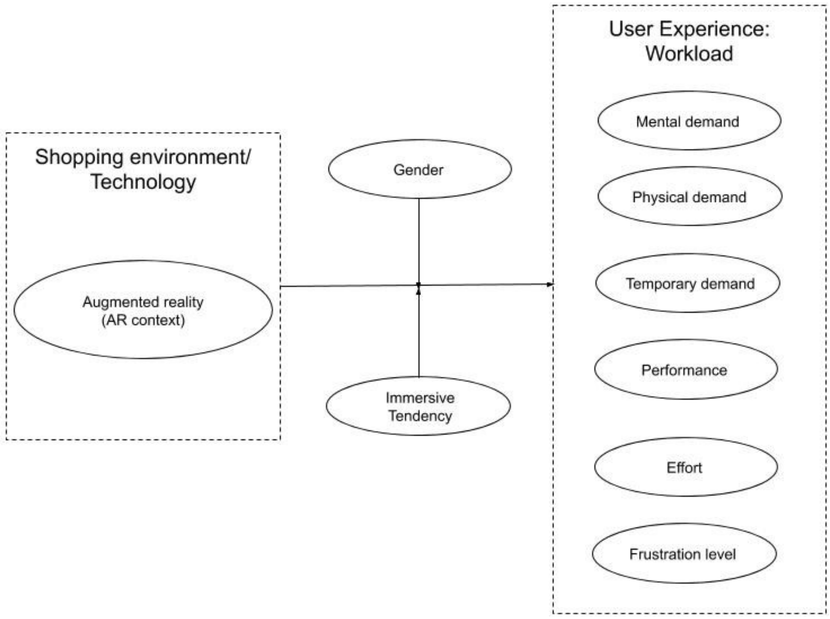


Figure 4. *The research framework in this thesis*

The main aim of this thesis is to investigate the difference in mental workload in the non-augmented and augmented reality shopping conditions. The thesis tested the mental workload about non-augmented and augmented reality shopping contexts from the point of view of user experience of digitalized shopping.

Due to the size of the product, the complete information of the product is often not fully displayed on the product itself. Even the information printed on the product may be inconvenient for consumers to read because of the font size, layout confusion, etc. Augmented reality technology allows information to be integrated into the environment and spatially registered with objects, which can help overcome the limitations of current product sizes. Compared to traditional printing on the product itself, AR-based products offer unique advantages in human factors.

In 2003, Tang et al. held an experiment that in the assembly task, the AR instructions relative effectiveness have been tested. The result showed that there is lower mental workload in the AR system. Haines, Fischer & Price (1980) pointed out that AR technology can cover 3D compounded computer graphics in the user's field of vision, and studies have shown that in the cockpit, head-down displays user pilots tend to have more head and eye movements than these pilots who using head-up displays. With the movement decrease of the head and eyes and extending the period that eye on the product during shopping, it is supposed to reduce the requirements of users in physical and increase their performance. By overlaying equivalent information on the product in a spatially meaningful way, the time it takes to search for information while shopping is reduced. Neumann & Majoros (1998) mentioned that by adding virtual information into reality, AR technology can be considered as "a complement to human cognitive processes". Using AR as a shopping environment can shorten the cost of attention switching between the shopping environment and tasks. AR technology can be used to increase consumer’s attention. Because the compounded computer graphics are merged with the user's field of vision, the user's attention can be drawn through labels, object highlighting, animation etc.

If AR technology works on reducing head and eye movement as well as attention switching, consumers should feel more relaxed and satisfied and take less time with the information searching. Thence, we forecasted:

H1: Compared to the traditional shopping context, the mental demand is lower in the augmented reality shopping context.

H2: Compared to the traditional shopping context, the physical demand is lower in the augmented reality shopping context.

H3: Compared to the traditional shopping context, the temporal demand is lower in the augmented reality shopping context.

H4: Compared to the traditional shopping context, the effort is lower in the augmented reality shopping context.

In shopping tasks, depression or annoyance can be made to consumers by cannot find the needed information correctly. Through a virtual way to present the information, AR technology can reduce negative emotions. Thence, we came up with the hypothesis:

H5: Compared to the traditional shopping context, the performance is better in the augmented reality shopping context.

H6: Compared to the traditional shopping context, the frustration level is lower in the augmented reality shopping context.

Suh and Prophet (2018) point out that in regard to AR technology, males tend to be more receptive than females. Munafo et al. (2017) also demonstrated that females are easier to feel the sickness than males when wearing the head-mounted display. Both of these two studies showed that females tend to have worse user experience than males in AR technology. Thence, the following hypothesis was developed:

H7: In the augmented reality shopping context, mental workload of males is lower than females.

Immersive tendency questionnaire that conducted by Witmer and Singer (1988) has shown that persons who have a higher score in the immersive tendency questionnaire are more easily to be immersed with the virtual. Thence, we predicted:

H8: In the augmented reality shopping context, the mental workload of the people who have a higher immersive tendency is lower.

5. THE EXPERIMENT DESIGN

5.1 Participants

In September 2019, we distributed flyers on the restaurant tables of Tampere University to advertise the recruitment of the experiment (see appendix). By scanning the QR code, Participants were asked to fill out a short online survey (including age, gender, income, education, height, immersive tendency, etc.) and self-booked the specific time to join the experiment after submitting the survey. In total, we recruited 40 student participants (20 female students and 20 male students) and randomly arranged them to join the different experimental conditions. Table 1 shows the demographic characteristics of the participant. The gender distribution of the sample is equal with male participants representing 50% and female participants representing 50%. All the participants are students, regarding age, most of the participants were between the ages of 20 and 29, accounting for 85% of the participants. Most participants currently doing their bachelor's degree (57.5%); 70% of the participants' height are at 161-180 cm. More than 82.5% of the participants had a monthly income from 0 to 999 euro, and 7.5% over 2000 euro. The detail demographic information described in table 1.

Table1. *Demographic information (n = 40)*

Variable		N	%
Gender	Male	20	50.0
	Female	20	50.0
Age	15-19	4	10.0
	20-24	24	60.0
	25-29	10	25.0
	30-34	1	2.5
	35-39	1	2.5
Education	Bachelor	23	57.5

	Master	14	3.0
	PhD	3	7.5
	151-155cm	2	5.0
	156-160cm	2	5.0
	161-165cm	8	20.0
Height	166-170cm	6	15.0
	171-175cm	6	15.0
	176-180cm	8	20.0
	Above 180cm	8	20.0
	0-499 euro	21	52.5
	500-999 euro	12	30.0
Income	1000-1499 euro	3	7.5
	1500-1999 euro	1	2.5
	2000- 2499 euro	3	7.5

5.2 Materials

5.2.1 Shop

For the experiment purpose, we built a simulated shop in the university. The area of the office is 4.24m x 5.09m = 21.6 ㎡. For the purpose to reduce the impact of environmental factors on participants' experimental experience, we made all the shelves same the type and same color and put the shelves on the three sides of the shop. The distance of every layer of the shelf is 31.5cm, the distance from the lowest layer to the floor is 89 cm. Due to the highest layer of the shelf is over 150 cm, might be too high to interact for some participants whose body shape is relatively small, thus in the survey, one question is about the height of the participants. When placing the shelves, as shown in figure 5, it was found that the shelf which is directly facing the door, there were many extra places on the sides. In order to prevent participants to go to the backside of the shelf, moreover, influenced the shopping experience, there are some curtains set up, to show participants the range of activity. In every condition, we have 141 records, and all the records are divided equally into 3 euros, 6 euros, and 9 euros. There are 54 records in the shop in total, the arrangement of the records is all randomly. After every participant done the experiment, no matter how many records they chose, we made up the corresponding numbers of records, the replenishments are also randomly picked as well. During the experiment, we controlled participants' shopping time and the information provided. Participants are asked to spend a full 10 mins in the shop. The researcher will knock the door when the shopping time ends. Every record has its relevant extra information, all this information is from website Discogs, which is a website and crowdsourced database of information about audio recordings, involving commercial releases, promotional releases, and so on. We screened useful information includes general information, track list, statistics, companies, and credits, and put all this information into PDF, figure 6 shows a sample of the extra information. In the Real shop condition, all this information will be printed and stick as stand in front of the records, so as to control the information presentation way, to make it present in the same way as in the AR shop condition. We encode all records as it will be easier when checking whether the found extra information and the records match or not. In addition, when uploading the scanning pictures of the records to the Vuforia database, it is more convenient to manage.

There are two Mi Home Security Camera 360° are settled in both left and right upper corners on the door side of the office in order to observe the participants during the experiment while do not disturb them (Figure 7). The camera has a dual motorhead that enables the camera to rotate and capture a full 360° horizontal view and 96° vertical view; 1080p, 2MP resolution. The camera has a rotation base that pre-installed to make it possible to place on everywhere even window ceiling and wall. Hence, the camera can be installed upright or inverted, moreover, the camera view is also possible to be inverted only with simple change of the camera setting. The camera supports Local MicroSD and Network Attached Storage (NAS). The data from SD cards (supports up to 64 GB) can be stored to NAS storage devices by using the network device or storage capability routers. Furthermore, by installing the application Mi Home, the real-time situation and recorded videos can be viewed on the smartphone and tablet, the Mi Home application supports Android 4.4/iOS9.0 or higher.

About the experiment length, after the participant comes to the shop in each condition, the first step is to ask them to use around 10 mins to fill up the pre-survey. And then, in the AR condition, as the participants need to have a small training for the HoloLens, the preparation time will be 2-3 mins. Afterward, the shopping time for each condition will be

10 mins. And after the shopping is done, participants will have 30 mins to fill out the post-questionnaire.

Hence, totally, the length of the experiment time will be around one hour.

a) The left side of the shop

b) The right side of the shop

Figure 5. *The second-hand LP Record shop*

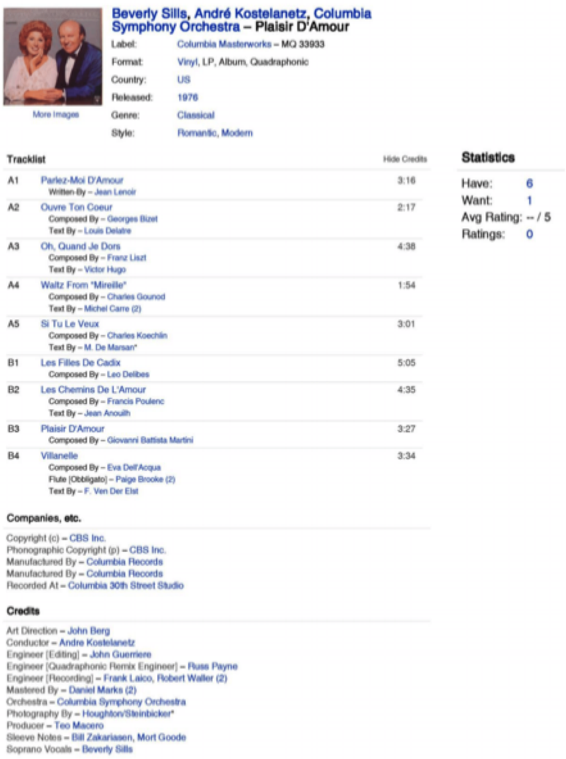


Figure 6. *An example of screened extra information for LP record*

Figure 7. *Mi home security camera 360°*

5.2.2 Products

About the experiment product, we choose LP records, there are four reasons. Firstly, the LP record is flat, compared to other products, the LP record is relatively not solid, therefore, is easier to modelling in the augmented reality. Secondly, in contrast with the normal CD, the LP record is bigger, thus, there are more information on it and participants can have more interaction with it. Thirdly, the LP record is unfamiliar for people, especially for the young generation, so participants tend to have less bias than other products. Fourthly, in contrast to other utilitarian products, LP record is the hedonic product, which means LP record is possible to produce pleasant and satisfying feelings, meet users' curiosity, lead to emotional gratification.

In total, we got 600 LP records for the experiment and all LP records are second hand since second-hand are mostly unknown, whereas participants tend to have more bias if the artist is very famous.

Likewise, as our participants are international, we only use English LP records in the experiment, to control the experiment environment language is same for all participants. However, the participants' native language is English, therefore, in the survey, participants have been asked about their English level.

Several studies have revealed that the product packaging has influence on users (Underwood, 2003; ST Wang, 2013). To be more specific, all the LP records were distributed into 8 conditions based on the combination of the three variables newness (old vs. new), brightness (dark vs. light), and graphics (complex vs. simple)

After dividing the records into 8 conditions, divide each condition records equally among the 2 experiment environments (Real and AR), to make sure all the environment has the same amount of same condition records.

5.2.3 AR Technology

In this experiment, we need to convert the real shop to the augmented reality shop with HoloLens. The following figure shows the implement principles and flow of augmented reality function in Unity 3D.

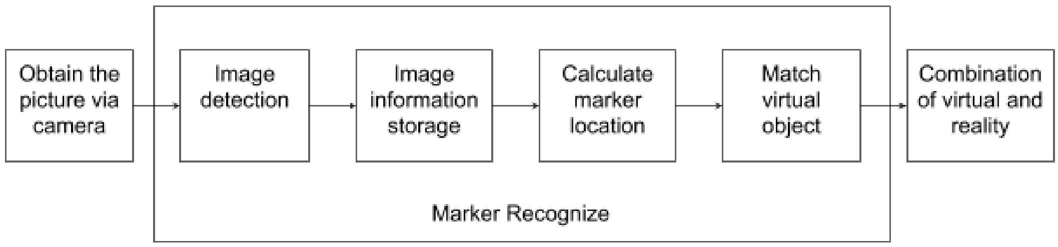


Figure 8. *Augmented reality implementation flow*

Vuforia engine is an indispensable part of the AR shop. Vuforia Cloud Recognition System is used, and it is suitable for the application with multiple targets. Instead of saving all the LP records information into the device, it is possible to save the information about targets into the Vuforia Cloud database (Cloud recognition, 2017). Vuforia provides development license key is free to use. The generated license key needs to be added into the Vuforia configuration in Unity. About the Single image target, only JPEG and PNG format are allowed, and the picture maximum size is 2MB. The width of the image is useful when tracking multiple targets, it will give additional metadata to the program to know roughly how large to expect the relative sizes of different image targets to be which is going to help in tracking. In Unity, one unit is normally one meter, and the dimensions of LP records used in the experiment are generally 31.43cm x 31.43cm, so the width is 0.3143.

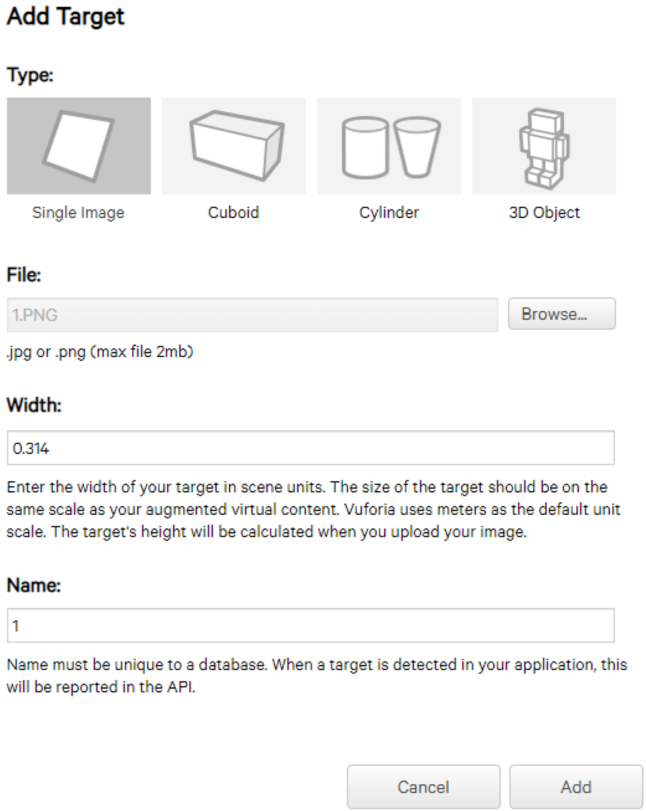


Figure 9. *Adding targets into Vuforia database*

Vuforia gives a rating as to how good target the application is going to be. The star rating defines whether the image target is suitable for detection and steady tracking. If the rating is less than 1 star, in that way, Vuforia will not try to recognize the target. The following figure 10 shows examples of the star rating.

Figure 11 shows the identified certain distinguishing features will be shown by click show features. A lot of facial and body features have been marked out and also where is high contrast like the edge of the bodyline into the background.

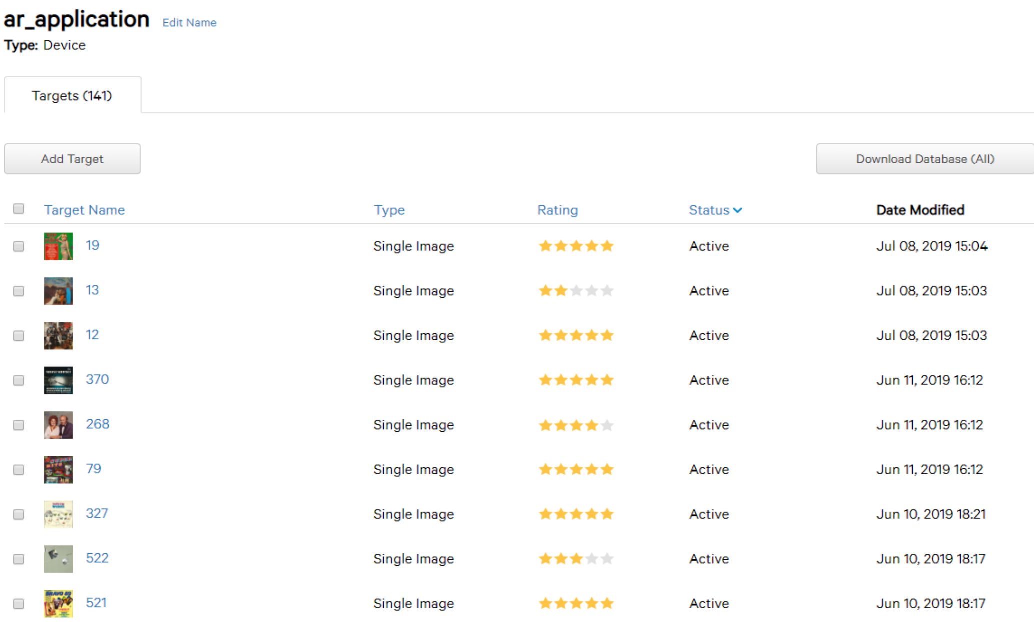


Figure 10. *The star rating for determining the quality of the uploaded image targets in Vuforia*

Figure 11. *Image target features*

In Unity 3D, it is possible to realize augmented reality interaction LP record shop design by implementing the Vuforia SDK, here are the following concrete steps.

Installing the Unity 2019.1.10 into Windows 10 pro and import Vuforia SDK into Unity.

Upload the scanned LP record cover picture into Vuforia engine database (the size of the single picture cannot over than 2M, picture file must be JPG or PNG, if the picture is grayscale, then jpg format is recommended), the database will automatically mark the identification points of the picture.

Download the database package and import into Unity, the package should include data sets (xxx.data), xml (xxx.xml), recognition image (xxx_scale.jpg; xxx_scale.png), figure 12 shows the situation of package property panel of augmented reality LP record shop recognition image.

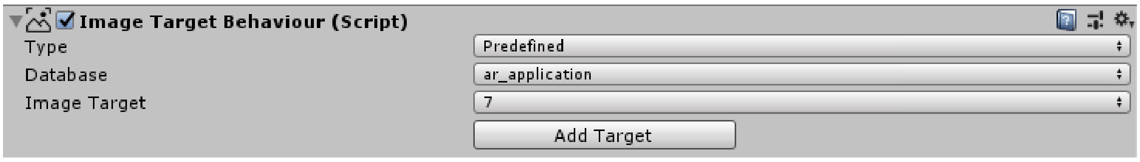


Figure 12. *Image target in the scene*

1. Add App license key, using to generate apk file and assure it can be built and run on the iOS or Android platform. App license key can be generated from license manager of Vuforia and add to the system, figure 13 shows the app license key used in the development.

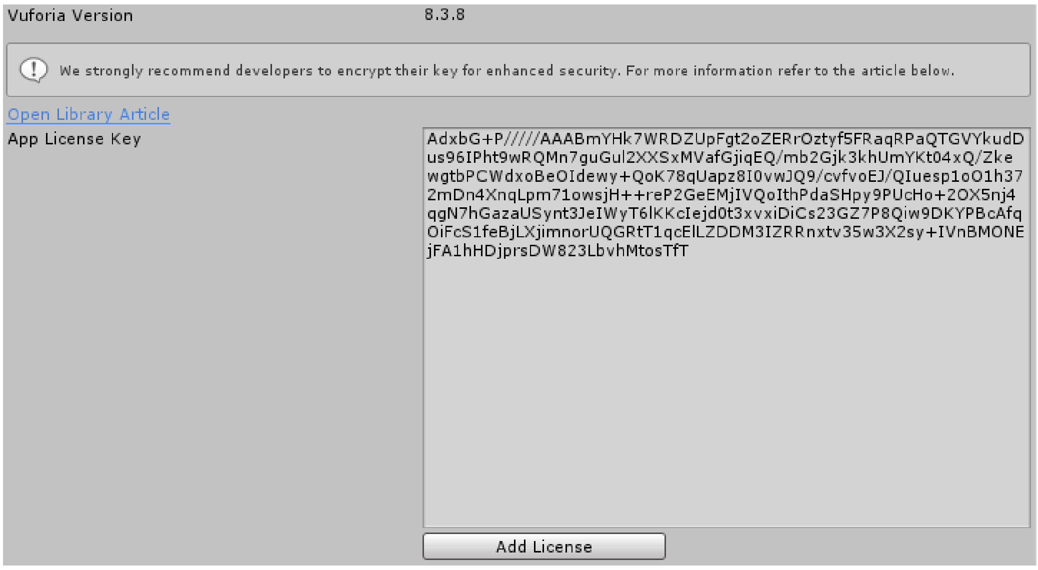


Figure 13. *App license key*

2. Create the scene, include ARCamera and ImageTarget two classes, in their property panel database and ImageTarget need to be checked. The Digital Eyewear in the Vuforia Configuration is not set at the moment. It requires to be changed to Optical See-Through and See Through Config is set to use HoloLens. Normally, when creating augmented reality application, MainCamera will be deleted, however, for each eye, there should be one rendering image to make sure when wearing HoloLens the image was seen in stereo, thus, HoloLens need it in order to track users' head and stereoscopic rendering. (Silvennoinen, 2017). Therefore, MainCamera need to be added to the scene.

3. MainCamera needs to be located in origin, where is the position of the head. The flag of MainCamera needs to be set as black similar to the ARCamera prefab. MainCamera will be used as the center of the anchor point for the ARCamera.
4. Run the application, when the camera recognizes the picture which matched with the recognition image added to the system, OnFound events will be triggered, while, if the recognition image disappears from the range of camera recognition, OnLost events will be triggered, the specific business logic of these two events have been handled in OnFound and OnLost. After reviewing, it is possible to release the application:

```
void OnFound(string trackableName){
// TODO Recognize successful logic processing, parameter trackableName is the name of xml
}
void OnLost(string trackableName){
// TODO Lost logic processing, parameter trackableName is the name of xml
}and then
```

5. Import all the extra information into the Unity (the format must be picture file), to superimpose the extra information on the top of the image target, a 3D object needs to be placed onto it, the extra information will be complemented as a texture onto the material of it. As by default before it only tracks one image target at once, however, there are 141 images in the database, thus it needs to increase the max simultaneous tracker in the AR Camera configuration (Figure 14) up to 141 to make sure all the pictures in the database can be recognized at the same time. Additionally, there will be 56 records in the shop simultaneously, when participants look at the records, too much pop up window shown at the same time will make the HoloLens interface too messy, with the purpose, we made a short code (Figure 15) to set that the extra information will not show automatically, only will be shown after click.
6. Build settings allow developers to select the target platform, based on the deployed project to regulate the settings and Build. Player settings are used for resolution and presentation options setting, set up the application icons, possessing some specific settings for the platform as well as settings for project publishing. As the following figure 16 shows, for HoloLens, the target build should be Windows. Universal 10 is compatible SDK of Windows 10, when using the HoloLens, it works as Windows 10,

thus, the SDK should choose to use Universal 10. D3D and XAML are the two selection for the build type. Here D3D was chosen as it required lower CPU consumption but possible to achieve more complex 3D effects (What is Direct3D 12. windows dev center, 2019). XAML is using for the project which has 2D and UI elements (XAML overview. windows dev center, 2018).

Max Simultaneous Tracked Images	141
Max Simultaneous Tracked Objects	141

Figure 14. *Max simultaneous tracked targets in ARCamera configuration*

```
Imported Object
SelectObj
Assembly Information
Filename                         Assembly-CSharp.dll
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using Vuforia;

public class SelectObj : MonoBehaviour
{

    //private Text label;
    public GameObject targetObj;
    private Transform childObj;

    // Use this for initialization
    void Start()
    {
        // gameObject.SetActive(false);
        for (int i = 0; i < targetObj.transform.childCount; i++)
        {
            targetObj.transform.GetChild(i).gameObject.SetActive(false);
        }
    }

    // Update is called once per frame
    void Update()
    {

//#if UNITY_EDITOR
        if (Input.GetKeyDown("n"))
        {
            for (int i = 0; i < targetObj.transform.childCount; i++)
            {
                targetObj.transform.GetChild(i).gameObject.SetActive(true);
            }

        }

        if (Input.GetKeyDown("m"))
        {
            for (int i = 0; i < targetObj.transform.childCount; i++)
            {
                targetObj.transform.GetChild(i).gameObject.SetActive(false);
            }


        }

        /*
            // Ray ray = Camera.main.ScreenPointToRay(Input.mousePosition);
            //    RaycastHit hit;
            //    if (Physics.Raycast(ray, out hit))
            //   {
            //        gameObject.SetActive(true);
            //    }
            //    else
            //    {
            //        gameObject.SetActive(false);
            //        //label.text = "";
            //    }
            // }
        //#elif UNITY_ANDROID
            if ((Input.GetTouch(0).phase == TouchPhase.Stationary) || (Input.GetTouch(0).phase == TouchPhase.Moved &&
Input.GetTouch(0).deltaPosition.magnitude < 1.2f))
            {
                Ray ray = Camera.main.ScreenPointToRay(Input.GetTouch(0).position);
                RaycastHit hit;
                if (Physics.Raycast(ray, out hit))
                {
                    gameObject.SetActive(true);
                    //label.text = hit.transform.name.ToString();
                }
                else
                {
                    gameObject.SetActive(false);
                    //label.text = "";
                }
            }
        //#endif
        */
    }
}
```

Figure 15. *Code for the object select*

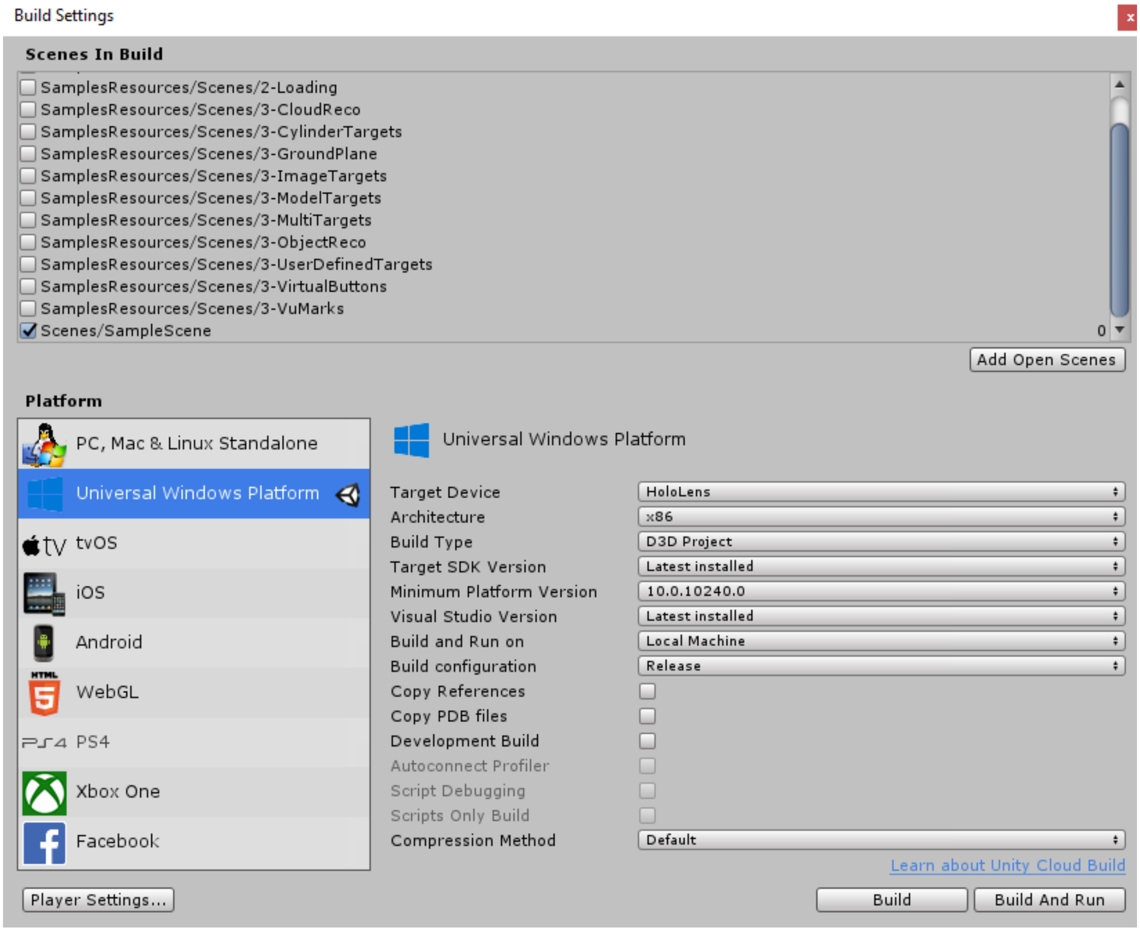


Figure 16. *Build settings*

Compare to smartphone and tablets, HoloLens is a wearable device, will not take up participants' hands, they are possible to interact with the records by both hands, have a better experience, and more similar as in other three conditions, thus, in this experiment, we used Microsoft HoloLens (table 2), mode setting as the following figure 17.

Table2. Features of *HoloLens*

	HoloLens
Weight	579g
Memory	64GB Flash 2GB RAM
OS	Windows 10
Processors	Intel 32-bit architecture Custom-built Microsoft Holographic processing unit (HPU 1.0)

	See-through holographic lenses (waveguides)
	2 HD 16:9 light engines
Optics	Automatic pupillary distance calibration
	Holographic Resolution: 2.3M total light points
	Holographic Density: >2.5k radiants (light points per radian)
	Spatial sound
Human	Gaze tracking
understanding	Gesture input
	Voice support
	Built-in speakers
	Audio 3.5mm jack
	Volume up/down
	Brightness up/down
Input / Output / Connectivity	Power button
	Battery status LEDs
	Wi-Fi 802.11ac
	Micro USB 2.0
	Bluetooth 4.1 LE
	1* Inertial Measurement Unit (IMU)
	4* environment understanding cameras
	1* depth camera
Sensors	1* 2MP photo / HD video camera
	Mixed reality capture
	4* microphones
	1* ambient light sensor

Figure 17. *Experiment device HoloLens*

5.2.4 Pilot test

To avoid the misunderstanding that might happen because of the ambiguous and unclear description in questionnaire and guideline, a polit test prior to the actual experiment was carried out. 10 volunteers from Tampere University came to shop in both shopping environments. After their shopping, the volunteers were given the preliminary questionnaire to fill. The volunteers have pointed out several questions involving confusing words, shopping length, unclear of the additional information, and clarity of the virtual information picture, etc. Based on their feedbacks, we modified part of the questionnaire and added explanation to some words in the instructions. For the guideline, we added the part for telling the prices of LP records are on the backside of those records. We also added a demonstration of “how to use HoloLens”. In the beginning the length of the shopping was 15 minutes, but some volunteers said it was too long and they want to leave before the shopping time ends. Thus, we shortened the shopping time to 10 minutes, and they were told not to leave in advance. About the unclear of the virtual information picture, we adjusted the picture distance in the Unity.

5.2.5 Measurement

We adapted the measurement items of immersive tendency from the study of Witmer and Singer (1998). A 7-point scale were used to measure all of the items related to immersive tendency, ranging from 1 (never) to 7(always) and 1 (not easily/good) to (very easily/good). The NASA Task Load Index (NASA-TLX) was used to measure mental workload (Hart & Staveland, 1988). There are six dimensions in the NASA-TLX.

1) mental demand, 2) physical demand, 3) temporal demand, 4) performance, 5) effort, and 6) frustration level.

Here, mental demand means the level of mental effort spent on completing the task. Physical demand implies the degree of physical effort spent during the task. Temporal demand expresses that whether time pressure existing to complete the task. Performance indicates that whether users satisfied with the effect to complete the task. Effort signifies the amount of energy that users spent to complete the task. About frustration level, it represents that disappointment after completing the task.

TLX includes two processes, the first step is to give scores to each of the factors to define the impact degree of that factor in the specific task. Each scale was equally divided into 20 intervals, from 0 (initial value) to 100 (maximum value), and the increment of each section is 5. The next step is to combine with the score and the weight of each factor, weighted average, and calculate the comprehensive workload value. Participants were asked to rank the six factors of workload from 1 (the most important factor) to 6 (the most unimportant factor).

Table3. *Measurement items*

Variables	Dimensions	Items	Source
User Experience: Workload	Mental demand	How mentally demanding was the task? (e.g. Thinking, deciding, calculating, remembering, looking, searching, etc.)?	Hart, S. G., & Staveland, L. E. (1988)
	Physical demand	How physically demanding was the task (e.g. pushing, pulling, turning, controlling, activating, etc.)?	
	Temporal demand	How hurried or rushed was the pace of the task?	
	Performance	How successfully were you in accomplishing what you were asked to do?	
	Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?	
	Frustration level	How insecure, discouraged, irritated, stressed and annoyed were you?	

Immersive tendency	Do you easily become deeply involved in movies or TV dramas? How good are you at blocking out external distractions when you are involved in something? When playing sports, do you become so involved in the game that you lose track of time? Have you ever gotten excited during a chase or fight scene on TV or in the movies? Do you ever become so involved in doing something that you lose all track of time?	Witmer B G, Singer M J. (1998) Measuring presence in virtual environments: A presence questionnaire. Presence Teleoperators and Virtual Environments, 7(3), 225–240.

5.3 Experiment Procedure

To enhance customers' real shopping experience, a scenario is made. "While you are passing by a second-hand LP record shop, you suddenly realize that you have a 10 euro gift card given by your friend last week. You find out that the expiry date of the gift card is today, which means you have to use it as soon as possible. Thus, you decide to use this gift card to get records for yourself before the shop closes. Remember the shop will close in 10 minutes."

Moreover, before the experiment starts the participants were told that they can really take the LP records which they choose during the experiment back as the gift, as this can enhance participants' reality shopping experience, to reduce their feelings of the experiment.

1. Participants come to the experiment room and were asked to fill out a short computer-based survey related to their prior knowledge about the music product and the scenario of the shopping task.
2. After reading the scenario, participants were given a 10 euros gift card (valued 10 euros). The experimenter was guided to the second-hand shop (next to the experiment room).
3. Taught the participant how to use the devices before the experiments start (only in AR condition).

4. Showed the sample of the record with the extra information paper pasted, and showed the participants the meaning of each part.
5. The experiment time for each participant was 10 minutes, during the experiments, participants were possible to interact with the LP records. In the reality shop, each participant could touch the LP record, turn around and read the information on the covers (but cannot open the LP record), and also the extra information from website DISCOGS which are printed into a paper and posted on the shelf. In the AR shop, participants were also possible to interact with the LP records and all the extra information was shown on the HoloLens. After participants choose the LP records they want, they just put them on the cashier desk and after the shopping time ends, the examiner came and calculated the price of the LP records which are put on the cashier desk and participants used their 10 euro gift card.
6. Participants were asked to fill the post-questionnaire which includes workload and each participant can get LP records they chose as presents.

6. RESULT AND ANALYSIS

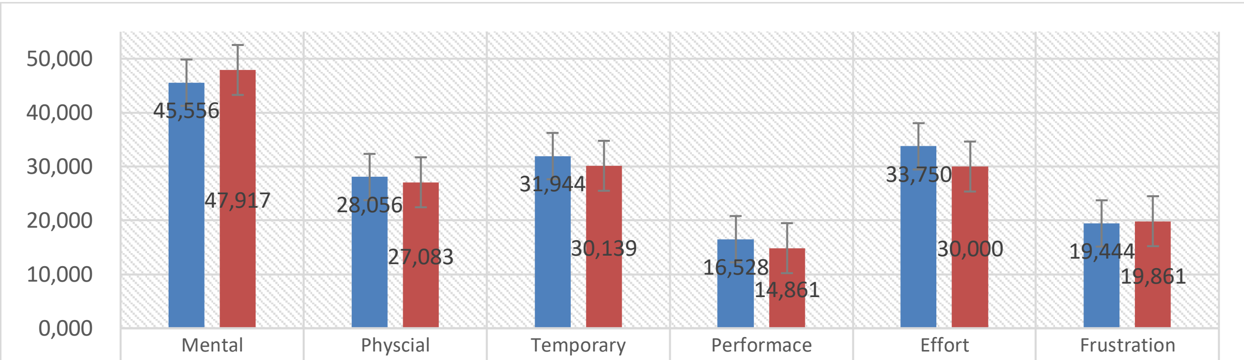
6.1 The main effect: User experience

This study compares the real shopping context with the AR shopping context to investigate what are the differences in the mental workload in different shopping environments and how much is moderating effect with gender and immersive tendency on AR on shopping workload and proposes several findings. The excel is used to calculate the weighted average of the workload in the Real and AR shopping context. Also, calculated the mean value of each dimension of workload.

Firstly, the experimental materials are divided into two versions according to the attributes of Real and AR of the shopping context. The mean value of each dimension of mental workload was presented in figure 18. Contrast with the real shopping context, physical demand, temporal demand, and effort are higher in the AR shopping context. On the other hand, mental demand and frustration are lower in the AR shopping context. Performance is also higher in the AR shopping context. There are six dependent variables in this thesis, a multivariate analysis of variance has been conducted which is the significance tests involving individual dependent variables separately. Table 4 displayed that there was a non-significant effect of non-augmented / augmented shopping environment on the six workload dimensions, $V = 0.30$, $F = 2.36$, $p = 0.052$. Moreover, separate univariate ANOVAs (table 5) on the out-come variables also indicated non-significant effect on mental demand $F = 202.5$, $p = 0.596$, performance $F = 40$, $p = 0.705$, effort $F = 2560$, $p = 0.063$, and frustration level $F = 180.63$, $p = 0.556$. However, there was a significant effect on the physical demand $F = 5062.5$, $p =0.017 < 0.05$, and temporal demand $F = 4840$, $p = 0.017 < 0.05$.

Secondly, combine the score of each dimension and its rank, the overall weight average of the workload was calculated, the result is presented in figure 19. Compare the overall weight average in two conditions, the overall workload in the augmented reality shopping environment is higher than in the real shopping environment. The participants are required to measure the workload after receiving the stimulated by the Real shopping context experimental materials and the AR shopping context experimental materials, the collected data results were manipulated using the independent sample t-test and the specific results are presented in table 6 and table 7: $F = 0.617$, $p = 0.437 > 0.05$ assumed variance is equal; $t = 2.057 > 0.7$, high correlation; $p = 0.047 < 0.05$, significant difference. The T-test is carried out in each workload dimension and the specific results are shown from following table 6 and table 7. In the Mental demand dimension, F = 0.427, p = 0.517 > 0.05, assumed variance is equal; t = 0.535, medium correlation; p = 0.596, insignificant difference. In the Physical demand dimension, t = 2.504 > 0.7, high correlation; p = 0.017 < 0.05, significant difference. In the Temporal demand dimension, t = 2.488 > 0.7, high correlation; p = 0.017 < 0.05, significant difference. In the Performance dimension, F = 3.255, p = 0.079 > 0.05, assumed variance is equal; t = 0.382, medium correlation; p = 0.705, insignificant difference. In the Effort dimension, F = 2.243, p = 0.142 > 0.05, assumed variance is equal; t = 1.913 > 0.7, high correlation; p = 0.063, insignificant difference. And in the Frustration level dimension, F = 2.915, p = 0.096 > 0.05, assumed variance is equal; t = 0.594, medium correlation; p = 0.556, insignificant difference. The result demonstrates the same with the ANOVA result which I have reported before in table 5.

Lastly, in the augmented reality shopping environment, Mental demand and Performance have been chosen as the most important factor, however, there is no big difference with other dimensions. Then again, in the real shopping environment, Mental demand also has been chosen as the most important factor, but with a huge difference compared to other dimensions (Figure 20).



	Mental	Physcial	Temporary	Performace	Effort	Frustration
AR	45,556	28,056	31,944	16,528	33,750	19,444
REAL	47,917	27,083	30,139	14,861	30,000	19,861

Figure 18. *The mean value of each dimension of workload*

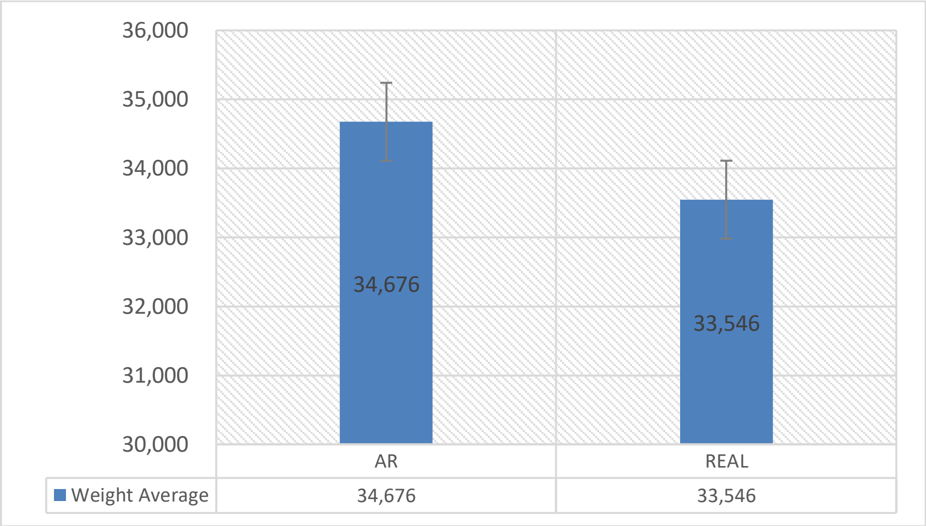


Figure 19. *Overall workload*

Table4. *Multivariate tests[a]*

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.799	21.801b	6.000	33.000	.000
	Wilks' Lambda	.201	21.801b	6.000	33.000	.000
	Hotelling's Trace	3.964	21.801b	6.000	33.000	.000
	Roy's Largest Root	3.964	21.801b	6.000	33.000	.000
group	Pillai's Trace	.300	2.360b	6.000	33.000	.052
	Wilks' Lambda	.700	2.360b	6.000	33.000	.052
	Hotelling's Trace	.429	2.360b	6.000	33.000	.052
	Roy's Largest Root	.429	2.360b	6.000	33.000	.052

Table5. *Test of between-subjects effects*

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	mental	202.500[a]	1	202.500	.286	.596
	physical	5062.500[b]	1	5062.500	6.271	.017
	temporal	4840.000[c]	1	4840.000	6.193	.017
	performance	40.000[d]	1	40.000	.146	.705
	effort	2560.000[e]	1	2560.000	3.659	.063
	frustration	180.625[f]	1	180.625	.353	.556
Intercept	mental	81902.500	1	81902.500	115.720	.000
	physical	29160.000	1	29160.000	36.120	.000
	temporal	37210.000	1	37210.000	47.609	.000
	performance	9922.500	1	9922.500	36.125	.000
	effort	42902.500	1	42902.500	61.318	.000
	frustration	15015.625	1	15015.625	29.369	.000
group	mental	202.500	1	202.500	.286	.596
	physical	5062.500	1	5062.500	6.271	.017
	temporal	4840.000	1	4840.000	6.193	.017
	performance	40.000	1	40.000	.146	.705
	effort	2560.000	1	2560.000	3.659	.063
	frustration	180.625	1	180.625	.353	.556
Error	mental	26895.000	38	707.763		
	physical	30677.500	38	807.303		
	temporal	29700.000	38	781.579		
	performance	10437.500	38	274.671		

	effort	26587.500	38	699.671
	frustration	19428.750	38	511.283
Total	mental	109000.000	40	
	physical	64900.000	40	
	temporal	71750.000	40	
	performance	20400.000	40	
	effort	72050.000	40	
	frustration	34625.000	40	
Corrected Total	mental	27097.500	39	
	physical	35740.000	39	
	temporal	34540.000	39	
	performance	10477.500	39	
	effort	29147.500	39	
	frustration	19609.375	39	

Table6. *Group statistics of workload*

Experiment Group		**N**	**M**	**SD**	**SE**
Overall Workload	AR	20	34.3750	19.24920	4.30425
	Real	20	22.5000	17.20830	3.84789
Mental demand	AR	20	47.50	27.023	6.043
	Real	20	43.00	26.178	5,853
Physical demand	AR	20	38.25	33.137	7.410
	Real	20	15.75	22.727	5.082
Temporal demand	AR	20	41.50	31.376	7.016
	Real	20	19.50	24.056	5.379
Performance	AR	20	16.75	20.792	4.649
	Real	20	14.75	10.818	2.419
Effort	AR	20	40.57	28.621	6.400
	Real	20	24.75	24.087	5.386
Frustration level	AR	20	21.50	25.603	5.725
	Real	20	17.25	19.158	4.284

Table7. *Independent samples test of workloads*

		t-test for Equality of Means						
		t	**df**	**Sig(2-tailed)**	**Mean Diff.**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
							Lower	Upper
Overall Workload	Equal Variances Assumed	2.057	38	.047	11.87500	5.77346	.18723	23.56277
	Equal Variances Not Assumed	2.057	37.532	.047	11.87500	5.77346	.18723	23.56277
Mental demand	Equal Variances Assumed	.535	38	.596	4.5000	8.413	-12.531	21.531
	Equal Variances Not Assumed	.535	37.962	.596	4.5000	8.413	-12.531	21.531
Physical demand	Equal Variances Assumed	2.504	38	.017	22.500	8.985	4.311	40.689
	Equal Variances Not Assumed	2.504	33.636	.017	22.500	8.985	4.311	40.689
Temporal demand	Equal Variances Assumed	2.488	38	.017	22.000	8.841	4.103	39.897
	Equal Variances Not Assumed	2.488	35.601	.018	22.000	8.841	4.063	39.937
Performance	Equal Variances Assumed	.382	38	.705	2.000	5.241	-8.610	12.610
	Equal Variances Not Assumed	.382	28.585	.706	2.000	5.241	-8.726	12.726
Effort	Equal Variances Assumed	1.913	38	.063	16.000	8.365	-.933	32.933
	Equal Variances Not Assumed	1.913	36.923	.064	16.000	8.365	-.905	32.950
Frustration level	Equal Variances Assumed	.594	38	.556	4.250	7.150	-10.225	18.725
	Equal Variances Not Assumed	.594	35.198	.556	4.250	7.150	-10.263	18.763

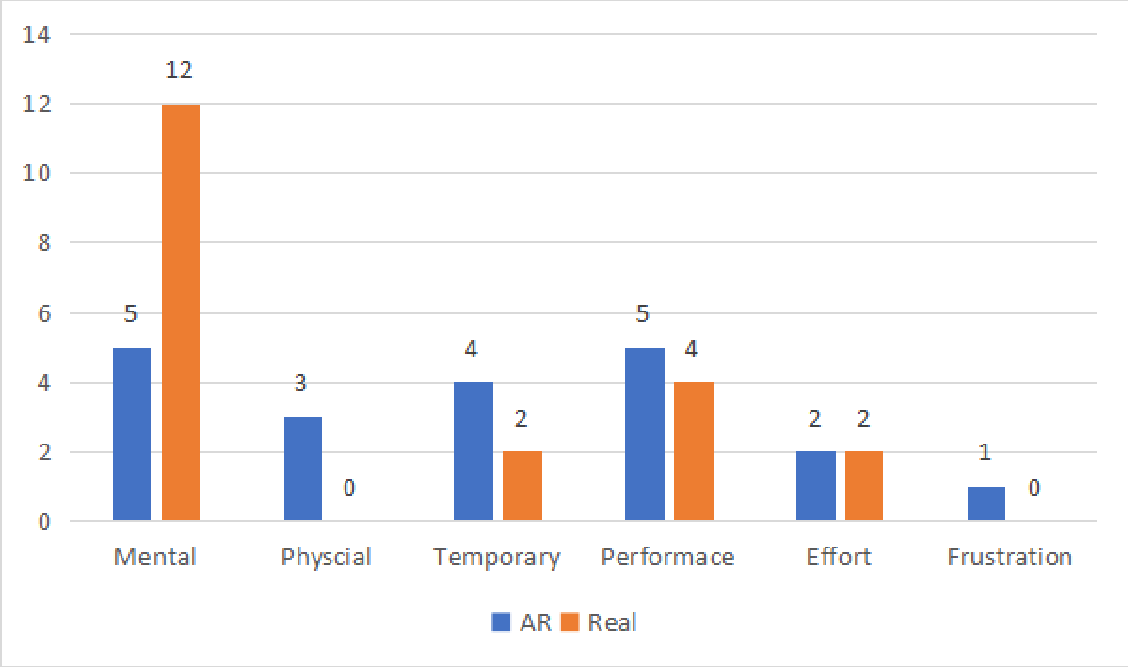


Figure 20. *The numbers of the most important dimension in different scenarios*

6.2 The moderating effect: Immersive tendency

The SPSS 25.0 statistical software was used to analyse the Immersive tendency in different shopping contexts. The non-parametric test method was used. P > 0.05 means that the difference was not statistically significant. The results are shown in table 8 and figure 21.

Table8. *Immersive tendency difference analysis table in different shopping contexts*

Group	N	M	SD	Z	P
AR	20	4.70	0.74	-0.014	0.989
Real	20	4.63	0.75		

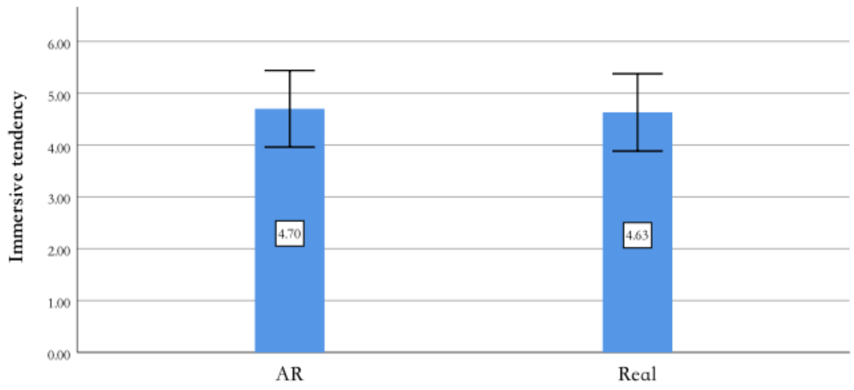


Figure 21. *Immersive tendency difference analysis graph in different shopping contexts*

It can be seen from table 8 and figure 21 that the significance of Immersive tendency non-parametric test in different shopping contexts is $p > 0.05$, indicating that there is non-significant difference in the Immersive tendency in different shopping contexts.

Using mental workload as the dependent variable, shopping context (Group), immersive tendency, and their interactions Group*Immersive Tendency as independent variables, multiple linear regression was established. Coefficients are shown in table 9.

Table9. *Multiple linear regression model*

Variable	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	28.699	31.117	0.922	0.363
Group	-8.404	43.466	-0.193	0.848
Immersive tendency	2.568	6.544	0.392	0.697
Group* Immersive tendency	**-1.263**	**9.206**	**-0.137**	**0.892**

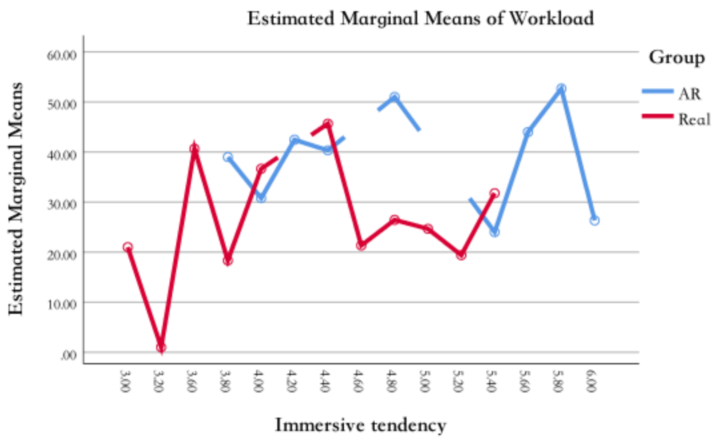


Figure 22. *The impact of the shopping context and the Immersive tendency on the workload*

The result shown in table 9 and figure 22, indicates that none of shopping context, immersive tendency and Group*Immersive Tendency significantly contributed to the mode ($p > 0.05$). This means that the effect of immersive tendency on mental workload will not be different depending on the shopping context. In other words, the immersive tendency does not moderate the user experience differences in shopping context, and this is disagreed with what this study expected.

6.3 The moderating effect: Gender

A two-way ANOVA was conducted on the influence of two independent variables (gender and shopping context) on the mental workload. The results are shown in table 10, table 11, and figure 23.

Table10. *Workload descriptive statistics for different genders and shopping context*

Gender	Group	N	M	SD
Male	AR	9	41.07	17.75
	Real	11	25.45	17.91
Female	AR	11	40.52	23.69
	Real	9	27.41	24.24

Table11. *Tests of between-subjects effects of workload*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2103.635	3	701.212	1.574	0.213
Intercept	44740.87	1	44740.87	100.423	0.000
Gender	4.809	1	4.809	0.011	0.918
Group	2042.509	1	2042.509	4.584	0.039
Gender * Group	**15.615**	**1**	**15.615**	**0.035**	**0.853**
Error	16038.932	36	445.526		
Total	63166.667	40			
Corrected Total	18142.567	39			

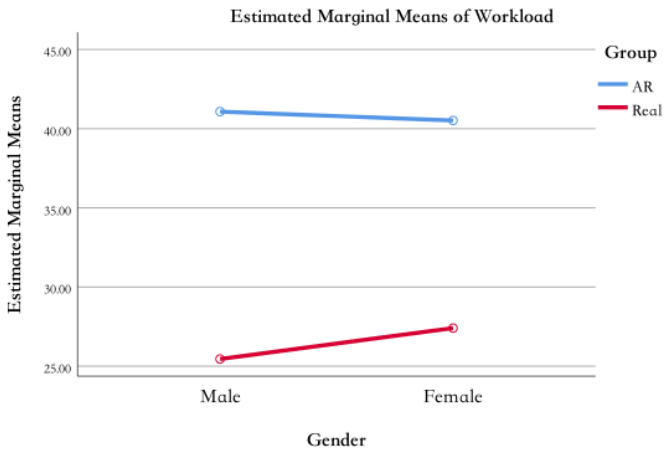


Figure 23. *Gender and shopping context impact on workload*

Gender included males and females, and the shopping context consisted of AR and real. F (1,36) = 0.011, p = 0.918 > 0.05, indicating that the effect for gender was not significant. The main effect for shopping context F (1,36) = 4.584, p = 0.039 < 0.05, indicating a significant difference between AR and real shopping context.

The interaction effect was non-significant F (1,36) = 0.035, p = 0.853 > 0.05.

However, different genders have different perceptions of workload. Following figure 24, it presents that in both augmented reality and real shopping context, Males' overall workload is higher than females.

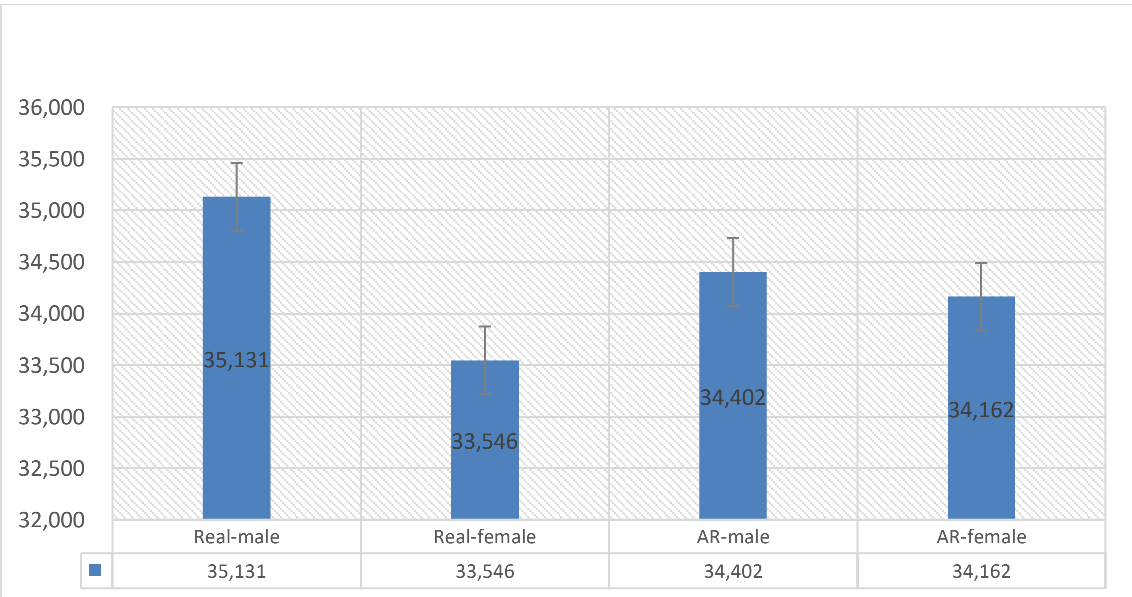


Figure 24. *The overall workload in different gender and different shopping contexts*

7. DISCUSSIONS AND CONCLUSION

7.1 Discussion

This thesis investigated the impact of augmented reality technology on the user experience in the digitized shopping based on laboratory experiment (N = 40), and also examined whether gender and immersive tendency play moderating roles in the impact of augmented reality technology on the user experience. The specific manifestations include the following:

7.1.1 The effect of augmented reality technology on the user experience

According to the results of experiments in the real and AR shopping conditions, this thesis concluded that in digitized shopping, augmented reality technology has effect on the user experience. When there is augmented reality technology in the shopping context, the user's mental workload is higher, the user experience is worse. When there is no augmented reality technology in the shopping context, the user's mental workload is lower, the user experience is better. For each dimension of the mental workload, there is higher physical demand, temporal demand, effort and better performance in the AR shopping context. Yet, lower mental demand and frustration level in the AR shopping context.

Such results also answered that the first research question of this thesis, compare to the non-augmented reality shopping environment, the mental workload indicated to be increased in the AR shopping environment. Furthermore, a separate univariate ANOVAs (Table 5) was conducted on the effect of shopping context on each dimension of NASA TLX rating. The effect was statistically non-significant on mental demand, performance, effort and frustration which means hypotheses H1, H4, H5 and H6 are not supported.

On the other hand, the effect was statistically significant on physical demand and temporal demand, indicated that hypotheses H2 and H3 are not supported. On the contrary, users' physical and temporal demand is higher in the AR shopping context.

There are several reports showed that AR technology can reduce people’s head and eye movements, and the mental workload in AR is lower (Haines, Fischer & Price, 1980, Tang et al., 2003).

However, the result of this thesis contradicts these discoveries, the mental workload in AR shopping environment is higher. Details to each dimension of the mental workload, physical and temporary, statistically significant demand is shown in the AR shopping environment. The reason is in all probability that participants are likely to be attracted by the information presented in the HoloLens then spent more time to read.

7.1.2 The interaction effect of augmented reality technology x gender for user experience

The individual differences that gender does not play a moderating role. It is concluded that in digitized shopping, the interaction between augmented reality technology and gender does not influence the user experience via the research of quantitative experiments. Hypothesis H7 is not supported. This result also answered the second research question a), gender has no moderate effect of AR on shopping workload.

In the previous studies, the views that the acceptance of augmented reality technology of males' is higher than females', and males tend to have better experience in AR technology than females were presented (Kosluscher et al., 2015; Suh and Prophet, 2018; Lawther and Griffin, 1986 & 1988). Thus, in this thesis, we hypothesized that males tend to have lower mental workload than females in the AR shopping environment.

However, in this thesis, the result shows that gender differences no longer exist in the AR shopping environment. Zhao and Zhao (2012) verified that "the frequency of males in digitized shopping is lower than females". Besides, another report indicated that "males tend to be cautious when making the purchase decision" (zhao et al., 2017). These two conclusions were proved in this thesis as well, figure 24 presented that regardless of whether there is augmented reality technology, the males' mental workload is higher than that of females' in the shopping context.

The result in this thesis perhaps is caused by the neutralization of males have higher acceptance of AR technology and males have higher mental workload in digitized shopping.

7.1.3 The interaction effect of augmented reality technology x immersive tendency for user experience

The individual differences that immersive tendency does not play a moderating role. It is concluded that in digitized shopping, the interaction between augmented reality technology and immersive tendency does not influence the user experience via the research of quantitative experiment. Hypothesis H8 is not supported. This result also answers the second research question b), immersive tendency has no moderate effect of AR on shopping workload.

The result of this thesis contradicts the idea that people with higher immersive tendency are more easily to be immersed with the virtual (Witmer and Singer, 1988). The reason is probably that AR shopping is built up of the real shopping environment and the virtual content displayed by the HoloLens application. However, there are not many virtual objects in the AR shop, thus, the effect of immersive tendency is not obviously shown in this study.

The major purpose to combine the traditional shopping with AR technology is to present the product content in a virtual way. To reduce the difficulty of the product content recognition and enhance user experience. The achieve this goal, it requires higher quality of virtual content that presented by AR technology.

7.2 Contribution

With the continuous development of augmented reality (AR) technology, the AR application will appear more and more in our lives. In terms of the shopping context, users have less experience for the AR applications and there is a lack of knowledge of the AR technology. Therefore, users may have conflicts with the expectation, cognition and usage habits of AR applications, thus, it is difficult to form a good user experience.

In this thesis, the related literature was systematically collected, reviewed, combed and analysed. Based on the previous research, the model framework of this thesis was determined. To a certain extent, it filled the gaps in theoretical research related to augmented reality technology and user shopping experience.

Secondly, in this thesis, a HoloLens AR shopping application has been established, and verified the effect of augmented reality technology and user shopping experience through experiments and questionnaires.

Thirdly, discoveries from this thesis provide useful advice for retailers who want to exploit AR technology as an enhanced offline shopping experience. Besides, this thesis found that in the AR shopping environment, mental workload is higher; there are higher physical and temporal requirements, more than that, there is no gender differences exist anymore.

7.3 Limitation and future research

There are a few limitations to this thesis. Firstly, only students participated in the experiment, which is not applicable to the general public. Even if students are reasonable samples for the thesis, since they are more familiar with augmented reality technology than others, and students are more likely to accept the AR technology than others. However, this experiment is only tested on the young generation, it cannot determine what is the effect when seniors use AR technology. Thus, in the future, the age of the participants should be extended. Secondly, this thesis only single type of product has been used, LP Record, in the future experiment, whether the results from this thesis are possible to validly remain to other kinds of products, observation is needed. Thirdly, the height and visual acuity of the participants are different. Some of the subjects have lower heights and may have difficulty accessing the LP Records on the top of the shelves; some participants may not have good eyesight and need to wear glasses, when using the HoloLens, there are different experiences with glasses and without glasses. Finally, the effect of the HoloLens AR application is not as what we expected. When participants turn their head toward the LP record, the virtual information should be present immediately, however, it didn't. Thus, participants need to go closer to the LP record and make sure the camera on the HoloLens aims to the LP record, and several seconds later, the virtual information window is shown. The result that mental workload in AR is higher, might be also influenced by that AR technology is not mature yet.

In the future, we can conduct in-depth discussions in a quantitative way. In the shopping context, how other mixed reality technology other than augmented reality technology influence the user experience can also be discussed in depth.

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APPENDIX A: QUESTIONNAIRE

Dear participant,

We are looking for volunteers (STUDENT ONLY) to take part in a study of shopping experience. As a participant in this study, you would be asked to spend a provided gift card, and to fill out our online survey. Participation is entirely voluntary and would take up approximately 1 hour of your time. The offline experiment will be conducted in Tampere University Hervanta Campus. During the experiment, the audio and video data will be recorded. All data will be coded so that your anonymity will be protected in any research paper and presentations that result from this study. In appreciation for your time, you will receive the products selected in the experiment task as your own (worth roughly 10 euros). You can take the products back home.

Please fill out this short survey that is mainly related to your basic information. It only takes 2 minutes to complete. You will be directly led to doodle and select a specific time to join the experiment after you complete this survey.

This research complies with the National Advisory Board on Research Ethics of Finland. Participation is voluntary and you have the right to withdraw from the study at any point. All the data provided on the questionnaire will be stored securely and anonymously, and will not be disclosed to third parties.

Thank you for participating in the research.

First part: Basic information

Gender:

A. Male B. Female

Age:

A. Less than 15 B. 15-19 C. 20-24 D. 25-29 E.30-34

F. 35-39 G. 40-44 H. 45-49 I. 50-54 J.55-59 K. Over 60

What is your height?
A. 150 cm and less B. 151-155cm C. 156-160cm D.160-165cm

E. 166-170cm F. 171-175cm G. 176-180cm H. Above 180 cm

Do you use glasses for reading?
A. YesB. No (if you have contact lenses, you can just select “NO”)

Current education background

A. Bachelor student B. Master student C. PhD student D. Other.

Income per month? (pre-tax)

0-499 euro B. 500-999 euro C. 1000-1499 euro D. 1500-1999 euro

E. 2000-2499 euro F.2500-2999 euro G. 3000-3499 euro H.3500-3999 euro

I. 4000 euro or more J. Confidentiality

Second part: Immersive Tendency

1. Do you ever become so involved in doing something that you lose all track of time?

1 2 3 4 5 6 7

Never Neutral Always

2. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

1 2 3 4 5 6 7

Never Neutral Always

3. When playing sports, do you ever become so involved in the game that you lose track of time?

1 2 3 4 5 6 7

Never Neutral Always

4. How good are you at blocking out external distractions when you are involved in something?

1 2 3 4 5 6 7

Not good Neutral Very good

5. Do you easily become deeply involved in movies or TV dramas?

1	2	3	4	5	6	7
Not easily			Neutral			Very easily

Third part: Worklod

Scenario: While you are passing by a second-hand LP record shop, you suddenly realize that you have a 10 euro gift card given by your friend last week. You find out that the expiry date of the gift card is today, which means you have to use it as soon as possible. Thus, you decide to use this gift card to get records for yourself before the shop closes. Remember the shop will close in 10 minutes.

Gift card: This gift card has 10 euro value. You can use it to buy any records in the shop. Please try to make the best purchasing decision because you can get the records and get them back home in the end. Remember you cannot get any amount of the gift card and you have to use it completely.

LP record: You can pick up records, turn around and read information. Each record has its own price tag on the back. There are 54 records in the shop in total. Just remember don’t open the cover to avoid scratching the record and each hand can only hold one LP record.

Extra information: We provide extra information for each record which can help you to make a better purchase decision. You can find e.g. the artist’s name, album title, released year, style, track-list, company, credit, and social-related information.

Time: You need to spend a full 10 minutes in the shop. The researcher will knock the door when the timer ends. You are not allowed to use the phone or watch during shopping.

Purchase decision: During the shopping time, you can put the records on the cashier table and change your selection at any time. We will only ask you to pay the LP records on the cashier table when the time ends. Thus, make sure the total amount of the selected products does not exceed 10 Euro.

Notice: If you need any help or feel uncomfortable during shopping, you will be offered to take a short break during the experiment and are welcome to request additional breaks.

6. Mental demand: how mentally demanding was the shopping task? (e.g., thinking, deciding, calculating, remembering, looking, searching)

Low (0) ⟷ High (100)

7. Physical demand: how physically demanding was the shopping task (e.g., walking, picking, turning, controlling)?

Low (0) ⟷ High (100)

8. Temporal demand: how hurried or rushed was the pace of the shopping task?

Low (0) ⟷ High (100)

9. Performance: how successful were you in accomplishing what you were asked to do in the shopping task? (Note: 0 = Good performance, 100 = poor performance. For example, if you mark "80", which means you had poor/low performance in the shopping task; if you mark "20", which means you had good/high performance in the task)

Good (0) ⟷ Poor (100)

10. Effort: how hard did you have to work (mentally and physically) to accomplish your level of performance in the shopping task?

Low (0) ⟷ High (100)

11. Frustration level: how insecure, discouraged, irritated, stressed and annoyed were you in the shopping task?

Low (0) ⟷ High (100)

Now, we would like to know the importance of each factor to your experience of workload in the shopping task that you just performed.

Please specify which factor contributed more (and less) to the workload for the shopping task you performed in the experiment. By dragging and dropping each item, you can order the following factors according to the importance to workload, from *1 = the most important factor* to *6 = the most unimportant factor*.

Explanation:

* Physical demand: how physically demanding was the shopping task

* Mental demand: how mentally demanding was the shopping task

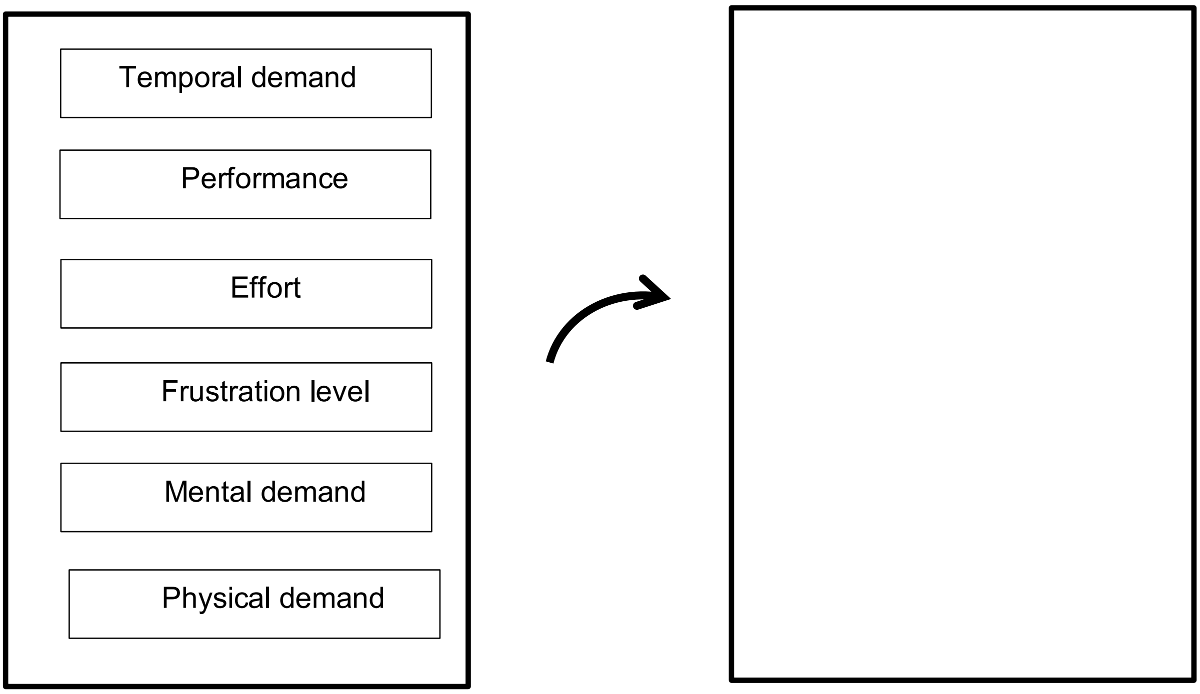
* Temporal demand: how hurried or rushed was the pace of the shopping task

* Performance: how successful were you in accomplishing what you were asked to do in the shopping task

* Effort: how hard did you have to work (mentally and physically) to accomplish your level of performance in the shopping task

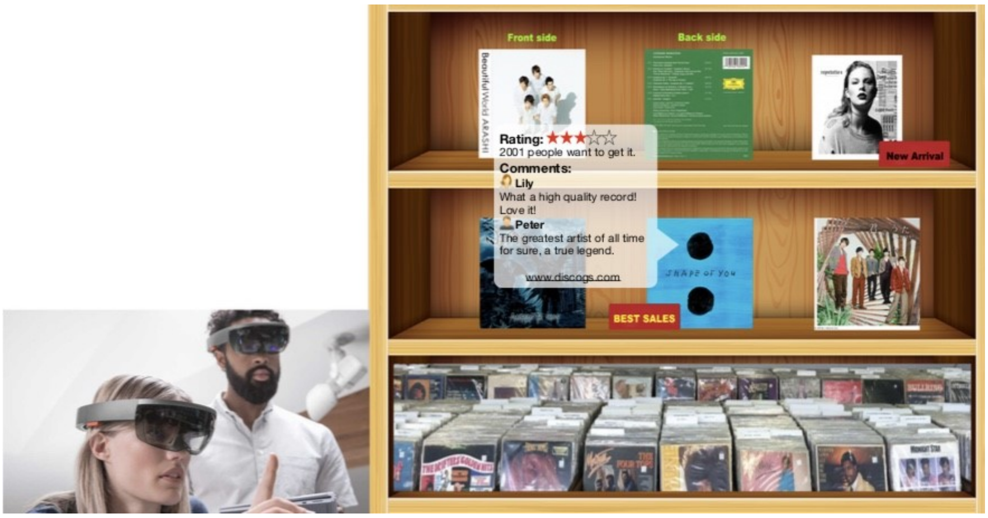
* Frustration level: how insecure, discouraged, irritated, stressed and annoyed were you in the shopping task

Drag items from the left-hand list into the right-hand list to order them.



APPENDIX B: PROTOTYPE OF SHOP DESIGN

a) Real Shop



b) Augmented Reality Shop

Figure 25. *Two experimental conditions*

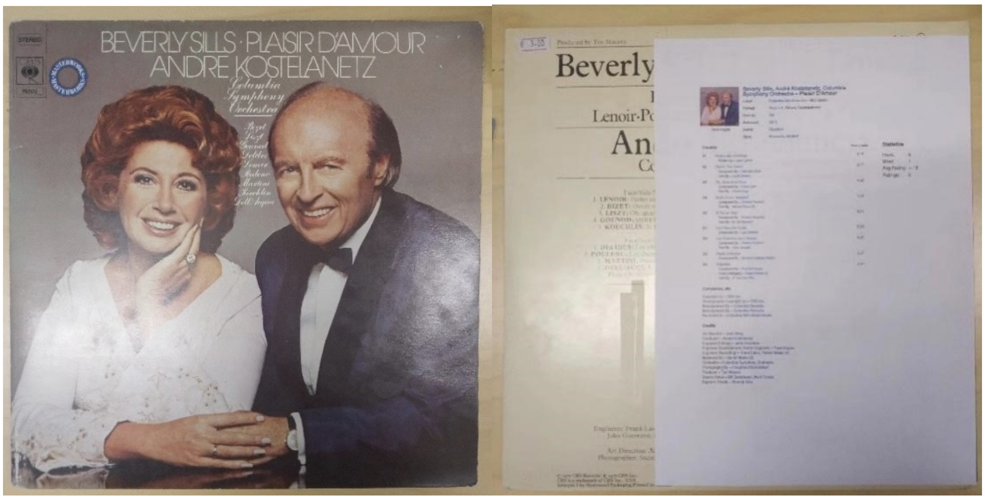


Figure 26. *Sample Record with the extra information*

Figure 27. *10-euro Gift Card*

Figure 28. *Experiment Advertisement*