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Tangible Virtual Assistants: A Study of Solution for Augmented Reality Interfaces and Interaction Techniques

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Preface

This Master Thesis is the final project of my Master in Interaction Design degree at the Norwegian University of Science and Technology (NTNU). The Interaction Design realm is broad. Before choosing the topic, I asked myself "what do I like?". I realized that I have a special enthusiasm for modern technologies which could be employed to enhance people's everyday life, and one of the technologies that I am interested in is Augmented Reality (AR). In the early autumn of 2018, I searched for journals which are relevant to the AR, and looked for the "Limitations", "What can be done better", "Future work" sessions in those documents. That was how I found the problem for my research topic. I also came up with the proposed solution - Virtual Assistant.

How to combine these two new technologies is exciting and challenging at the same time. In semester 3, I utilized the Specialization Course and Research Project Planning to scrutinize the backgrounds of Augmented Reality and Virtual Assistant. At the end of semester 3, I had the idea of developing an AR mobile app to test my hypotheses. I started to build the prototypes in the early spring of 2019. The development process encountered numerous obstacles as I had to be acquainted with many platforms which I had not known before, such as ARKit, 3D character animation, and After Effect.

Ultimately, I created the AR prototypes that not only used to examine my hypotheses but also can solve a problem that people usually encounter when shopping in supermarkets. Through this project, I have learnt valuable knowledge and experiences that would be used repeatedly in my working life. As well, I believe that the findings of this study will inspire other people those who are interested in Augmented Reality and Virtual Assistant.

01-06-2019

Acknowledgment

Abstract

This research explores the combination of two technologies - Augmented Reality (AR) and Virtual Assistant (VA). AR has been developed for several decades and has high potential of being applied in various industries such as commercial, education, entertainment, navigation, etc. However, AR contains limitations and restraints that prevent itself from becoming ubiquity. Those issues come from tracking technique, user interface, and interaction technique. This study focuses on the user interface problem and proposes virtual assistant as a solution. Virtual assistant has been employed widely and become more and more functional. Many technology giants apply VA to their products, such as Apple Siri, Google Assistant, Microsoft Cortana, Amazon Alexa, and so on. In this thesis, virtual assistant is hypothesized as an element that reduces information overload in AR user interface, increase the effectiveness of task performance, and enhance engagement between users and AR apps. Furthermore, VA is proposed to include appearance as a life-like character or animal; thus, it is named as Tangible Virtual Assistant.

Two prototypes of an AR app, one with graphics element only as a standard AR app and the other one with VA, are developed for the user study. Both quantitative and qualitative data are collected and analysed. The results show that the VA app significantly reduces information overload and increases the effectiveness in comparison with the Graphics app. Nevertheless, the hypothesis of enhancing engagement is not supported. This aspect requires further development and research.

Definitions

- **VA** - Virtual Assistant
- **TVA** - Tangible Virtual Assistant
- **AR** - Augmented Reality
- **VR** - Virtual Reality
- **HCI** - Human Computer Interaction
- **UI** - User Interface
- **UX** - User Experience
- **VUI** - Voice User Interface
- **AI** - Artificial Intelligence

1   Introduction

Many technology experts have commented on the enormous potentials of augmented reality (AR) - "I can see uses for it in education, in consumers, in entertainment, in sports. I can see it in every business that I know anything about", said Tim Cook from Apple (Kelion 2017). Nevertheless, although AR has been developed for many decades (Zhou et al. 2008), it has not turned ubiquitous yet, aside from the popular AR game - Pokemon GO. The AR technology, in fact, contains many challenges and limitations in the fields of tracking techniques, user interfaces, and interaction techniques.

Singh & Singh (2013) has mentioned that the mission of AR is "to help users manage today's information overload"; however, the 3D-world interfaces of AR have the same problem as the traditional 2D interfaces, which is the overwhelming information that distracts users. In AR, it could be even aggravating due to a multitude of graphical elements overlaid on the physical environment. For instance, in Figure 1, the virtual information occupies considerable space of the screen. Too many information displayed at the same time confuses users where to focus on. In addition, the details block a large portion of the real environment that may cause danger to the driver. In another case, the Audi team created the AR engine assembly application to help their employees to assemble engines faster and safer. However, Audi staff struggled to perform tasks in that AR application; the project was failed due to the information complexity (Technologies n.d.). Regarding the organization of augmenting information, Singh & Singh (2013) commented that "an AR application that presents all the information at once might serve only to confuse and mislead the user."

Figure 1: Augmented reality GPS Drive/Walk Navigation app. Source: Singh & Singh (2013)

In response to that problem, this research investigates the new interaction method, which is to include a virtual assistant (VA) in an AR app. VA such as Siri becomes the dominant feature in mobiles and smart home devices. It is the embodiment of artificial intelligence software employed to reduce the physical interaction between human and computer (Benyon 2014). With the continuing advance technology, VA gains more and more significant functions that can be applied in many aspects to enhance user experience. In this research, VA is proposed to be the solution for information overload in the interface of augmented reality. It is also suggested to include a look for VA in order to enhance the engagement between users and an AR application. Virtual assistant with appearance is named as Tangible Virtual Assistant (TVA) in this study.

An AR app comprising VA/TVA would have its information presented in a simple and clear way. The physical interaction is also reduced as people can interact with the app via voice commands. Thus, users can get rid of information overload and perform their tasks efficiently. In this research, a user study is conducted to compare the difference between the AR apps with and without a virtual assistant. Its results either support or refute the hypotheses established in the next chapter (section 2.3).

1.1   Keywords

virtual assistant, augmented reality, human-computer interaction, information overload, effectiveness, engagement.

1.2   Justification, Motivation and Benefits

Hollywood science-fiction movies have blown our mind with several futuristic virtual assistants. One of the most outstanding samples is JARVIS from the Iron Man movie. JARVIS stands for Just A Rather Very Intelligent System (D'Orazio 2015). He could generate holography, communicate with the user by voice, give advice, run house security system, and so on. Mark Zuckerberg, the Facebook CEO, has brought this virtual assistant to life by building his own personal smart home assistant which he described as "kind of like JARVIS in Iron Man" (Heath 2016). Besides, Apple's Siri, Microsoft's Cortana, Amazon's Alexa, Google Assistant, etc. are being developed with notable features that empower the modern VA. Klusch (2001) commented that today VA has been deployed in different settings such as industrial control, information retrieval, personal assistance, games, and many others. In fact, VA has high potential in various aspects. They can be employed in different interactive systems to enhance people's everyday life.

The question is whether VA can be applied to improve further user experience in AR environment. This master thesis aims to explore this uncertainty, focusing on VA as the solution for simplifying AR's user interface. If the hypotheses are supported, interaction designers will have a new approach to solve the problem and enhance user experience. It will also generate opportunities for businesses to provide better, fun, and engaging services to their customers through AR apps.

1.3 Research Questions

The research questions to be addressed in this study are:

1. What are the fail points of augmented reality, especially in user interface and interaction techniques?
2. How to enhance user experience in augmented reality?
3. What are the capbabilitites of virtual assistant in human-computer interaction?

   - What has virtual assistant been employed in the current technology?
   - How does virtual assistant resolve information overload?
   - How does virtual assistant impact the effectiveness of the interaction?
   - Does virtual assistant improve engagement between users and interactive systems/products?

4. Can virtual assistant be employed to augmented reality? If yes, how will it affect the augmented reality experience?

These research questions will be explored in Chapter 2 - Existing Literature. Following that, hypotheses are established (section 2.3).

1.4 Planned Contributions

Through this study, the researcher hopes to contribute several findings to the interaction design community:

- To amplify the competence of AR apps, make AR more practical and become more ubiquitous as it is supposed to be.
- To bring the virtual assistant to another level - tangible virtual assistant, a feature that would be helpful and playful at the same time.
- The experiment of incorporating virtual assistant in AR is not only to explore another capability of VA in the new environment, but also to find a solution for the problem in AR interfaces. The results will reveal if a VA helps an AR app to reduce information complexity, improve effectiveness, and enhance engagement.

The research outcomes will provide valuable information for other researchers who are interested in AR and VA.

1.5 Thesis Outline

This thesis consists of 7 chapters.

Chapter 1 introduces the problem in user interface of augmented reality and proposes virtual assistant as the solution. It also includes the justification, motivation, and benefits of this study. As well, the research questions and planned contributions to the design community are mentioned.

Chapter 2 provides theory, background, and existing literature regarding augmented reality and

the virtual assistant's role in human-computer interaction (HCI). The related work reflects the capacity of virtual assistant in improving the usability and user experience in the HCI. At the end of this chapter, the hypotheses are formed.

Chapter 3 describes the methodology used to examine the hypotheses. The Self-reported metrics are applied to compare the two prototypes. Also, this section includes the vital components in the Experimental Design such as tasks, questionnaires, and the step-by-step procedure. The last part of this chapter states the ethical and legal considerations of the research.

Chapter 4 presents the process of developing the two prototypes - Graphics and Virtual Assistant apps, and how they are operated to experiment.

Chapter 5 displays the quantitative data results of the characteristics (information overload, effectiveness, engagement) that this study is exploring.

Chapter 6 discusses the findings in the previous chapter and reveals its reasons by going through the collected qualitative data.

Chapter 7 reflects on the three aspects: (1) the contributions to the interaction design society, (2) learning outcomes for the researcher, and (3) future development and research.

1.6   Abbreviations and Terms Used

Information Overload: happens when information appears as a hindrance rather than aid, even though that information is potentially helpful (Bawden & Robinson 2009).

Effectiveness: is measured by the "percentage of tasks successfully completed, and percentage of users successfully completing tasks" (Benyon 2014), p.256).

Engagement: relates to enjoyable user experience integrated by elements of positive affect, aesthetic and sensory appeal, attention, novelty, and interactivity (Obrien & Toms 2008).

Virtual Assistant (VA): is defined as artificial intelligence (Al) computer programs. They work as intermediaries between human and interactive systems (Benyon 2014).

Tangible Virtual Assistant (TVA) is described as virtual assistants that visible to users. They appear as life-like characters, usually with human look or animal look.

Augmented Reality (AR): refers to a system that supplements the real world with virtual objects (Azuma et al. 2001).

Human Computer Interaction (HCI): is described as "the design, evaluation, and implementa-

tion of interactive computing systems for human use" (Rogers & Sharp 2011).

User Interface (UI): is computer-mediated means that facilitate communication between people, or between human and an artefact (Marcus 2002).

User Experience (UX): has three main characteristics (Tullis & Albert 2013):

- A user is involved
- The user is interacting with a system, a product, or anything with an interface
- It is of interest, and observable/measurable

Voice User Interface (VUI): enables voice interaction between human and devices via auditory, visual, or tactile interfaces (Baker 2018).

2   Theory, Background, Existing Literature

This chapter contains three main parts - (1) an overview of the Augmented Reality (AR), which has been discovered in the Specialisation Course II IMT4882 (Lam 2018a); it describes the definition of AR, the fail points in AR interfaces, and the elements that enhance user experience in AR environment. (2) an exploration of Virtual Assistant (VA), this part discovers the capabilities of VA in the current technology and examines how VA is utilized in interactive products and systems. (3) the hypotheses are established based on the theory and existing literature in part (1) and (2).

2.1   Augmented Reality

2.1.1   Definition of Augmented Reality

Augmented Reality (AR) is positioned between the real environment and Virtual Reality (VR) on the Mixed Reality Continuum (Figure 2). Different from VR, AR amplifies the real world instead of creating a simulated environment (Olsson et al. 2011). Azuma (1997) defined AR as the technology that supports the compound of virtual and real worlds, and encourages real-time interaction. Nunes et al. (2017) added to this definition by describing AR as a platform where the view and perception of the reality are enriched by virtual information elements (e.g., text, sound, graphical images). When the physical and virtual worlds are perfectly blended, AR produces exceptional immersive experience (Klopfer & Sheldon 2010) and stimulates enjoyment for users (Joseph & Armstrong 2016).
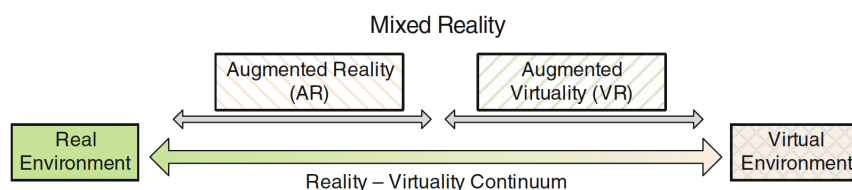
Figure 2: The mixed reality continuum. Source: (Olsson et al. 2011)

The AR concept has been developed since 1960s (Zhou et al. 2008). It is applied in such ordinary contexts that we may not realize. For instance, in the automobile parking assistance system, the actual distance between the vehicle and surrounding obstacles is displayed on the screen to inform a driver (Li & Fessenden 2016) (Figure 3). In the Google Translate app, when people face the camera to the texts on signage, menu, or letter, the app directly translates the messages. In the new feature of Facebook, users can play with the face effects to change their appearances through the camera. AR also aids education; it provides students with opportunities to

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interact with objects or experience phenomena that are not accessible in the real world (Klopfer & Sheldon 2010). Many AR applications have been generated and show its capacity in various fields such as commercial, navigation, education, entertainment, etc. Especially, AR also works in other cases that might surprise some of us, which is "emergency management and disaster relief operations" (Nunes et al. 2017).
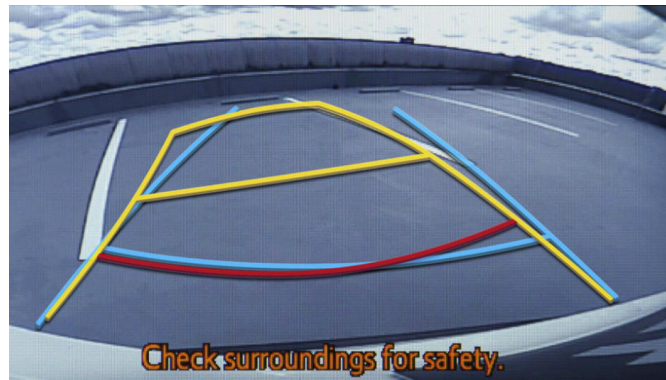
Figure 3: AR applied in rear-parking assistance. Source: (Li & Fessenden 2016)

2.1.2 What Are The Fail Points of Augmented Reality, Especially in User Interfaces and Interaction Techniques?

There are many reasons that cause an AR application to fail. In this study, it takes a glimpse of the technological problem and focuses on issues relating to user interfaces and interaction techniques. Among the technical problems, tracking technology is the most challenging part. How to make the virtual objects accordingly align with the environment has been the unsolved task since the first days of AR. This problem causes not only a shoddy app but also users' frustration. In his research of AR in education, (Wu et al. 2013) noted that GPS errors lead to students' annoyance and teachers remarked it as the extreme issue. Tracking failure is even worse when an AR app is operated outdoor. Marker-based tracking is the method that triggers an app to display its virtual objects; however, it usually does not work well in large scale navigation. To define distinguishable objects for outdoor markers is not always obtainable (Zhou et al. 2008). This difficulty explains why people playing Pokemon Go occasionally find their characters in some strange spots, for instance, "on top of a cat" (Dhillon & Partners 2019).

The second problem comes from the user interface design. Information overload happens not only in traditional 2D interfaces but also in the 3D environment of AR. Some AR apps violate the usability concept when displaying too much information and making it difficult for users to get the content or perform tasks. In comparison with traditional interfaces, AR even exacerbates this problem since it contains multiple types of augmented objects that could be displayed all together (Singh & Singh 2013). In his study, Wu et al. (2013) remarked that the AR environment generates opportunities for learning, but at the same time, it overwhelms students with an

abundance of information and complicated tasks to complete. It also requires many technological devices to operate. Similarly, in AR tourist apps, the visualization of retrieval search results is clutter and overload. It significantly reduces the legibility of information (Yovcheva et al. 2014). Moreover, the complicated and expensive design in AR could lead to discomfort and deficient depth perception (Kerawalla et al. 2006).

Another issue is about the dilemma in AR. An ideal mobile AR app is an app that has its virtual information and the reality are seamlessly aligned. However, there are situations where the reality and fantasy are merged and produce the mixed reality that causes confusions (Wu et al. 2013). For instance, in the research of mobile educational games, Klopfer (2011) mentioned that some students could not figure out where the reality starts and the game ends. Moreover, losing track of the real environment also threatens the physical safety of students. The issue of neglecting the real world when using a mobile AR service has caused some accidents to the Pokemon Go's game players and the people around (Joseph & Armstrong 2016). Therefore, when developing an AR app, designers should always consider the safety aspect for users.

2.1.3   How to Enhance User Experience in Augmented Reality?

User experience (UX) is defined in many ways by different researchers. To Hassenzahl & Ullrich (2007), UX is combined by the consequence of users' internal state (e.g., motivation, mood, expectations) with the attributes of the system (e.g., usability, complexity), and the context of use. Desmet & Hekkert (2007) divided product experiences to three types: aesthetic experience, experience of meaning, and emotional experience. Aesthetic experience refers to the enjoyment of users' sensory modalities. Experience of meaning relates to personal or the symbolic importance of that product. Emotional experience describes the feelings, emotions of users (e.g., frustrated or enjoy) towards the products. Olsson et al. (2011) noted that UX goes beyond usability in interaction design, which includes efficient, effective, and satisfactory. It covers the emotional relationship between users and products. Emotional concept in AR not only provides enjoyment but also surprise, liveliness, and playfulness. To add on, he insisted that the success of AR mobile services depends on how much designers understand their target users' requirements and expectations. Li & Fessenden (2016) affirmed this conclusion by stating that the developer and design team will produce a successful and effective AR service if they gain an in-depth understanding of users' goals and contexts.

Appealing user experience also comes from the quality of AR's technology. According to Li & Fessenden (2016), its characteristics should include: (1) adapt to changes from users' environments and respond contextually, (2) understand gestures and actions with minimal direct commands from users, (3) provide freedom to users' movement. However, there are many AR projects developed on the wrong track as they are focused more on technology-centred instead of user experience. The AR research community seems not to concentrate enough on the user experience in mobile AR services (Olsson et al. 2011). To balance between UX and technology, firstly, designers should consider users' pain points, then employ technology as the tool to solve those

problems and fulfil users' expectations.

According to Ishii & Ullmer (1997), information is displayed as "painted bits" on devices' screens, and graphical user interfaces are lack of deploying the human senses and skills that people have developed through interacting with the real world. Although the comment was stated twenty years ago, this situation persists. In his project - the "ambientROOM", Ishii & Ullmer (1997) proposed the idea of connecting the gap between the cyberspace and the physical world by taking advantage of human's multiple senses to apply to human-computer interaction. Though his project focused on ambient media for background awareness, the concept of a seamless connection between the virtuality and the reality should be utilized to enhance user experience in AR. Similar to the "seamless interfaces" idea of Ishii & Ullmer (1997), Zhou et al. (2008) suggested to transform the world itself into the interface by making use of natural physical affordances. This way would help to intensify legibility and generate the seamless interaction between users and information.

2.2 Virtual Assistant

2.2.1 What Has Virtual Assistant Been Employed in The Current Technology?

In some document (e.g., Designing Interactive System (Benyon 2014)), virtual assistants are called as virtual agents. To be consistent in denomination, it is titled as virtual assistant (VA) throughout this paper. Benyon (2014) defines VAs as artificial intelligence (AI) computer programs. They work as intermediaries between human and interactive systems. Most of virtual assistants' work relate to activities such as planning, scheduling, searching and controlling computer networks. The modern VAs' system consists of three modules, which are the speech-to-text (STT) engine, the logic-handling engine, and the text-to-speech (TTS) engine (Pant 2016). Figure 4 displays the virtual assistant workflow.

Figure 4: Virtual assistant workflow. Source: (Pant 2016)

- Speech-to-Text Engine (STT): is in charge of converting speech input from users to text string that could be operated by the Logic Engine. The system also includes noise cancelling for better voice record. It then employs natural language processing (NLP) to transform voice to text string.
- Logic Engine: is the brain of a VA. It receives text string from the STT and applies a series of If - then - else clauses to retrieve the proper action/answer that response to the specific inputs. Thereafter, Logic Engine sends the output to the TTS.
- Text-to-Speech Engine (TTS): communicates with users by receiving output from the Logic Engine and transforms it into speech. This component makes the VA more humane instead

of showing the answer by texts only.

Nass & Brave (2007) believe that people are wired for speech. Voice-based communication will enhance the interaction experience and build up the relationship between users and machines. In fact, human has the natural ability of recognising difference voices and tend to use speech as the fundamental method of communication. The three-component system of a VA erases the physical interaction; it generates entire natural interaction as between human beings.

In 2011, when Apple first time introduced Siri as a personal assistant, it could only perform simple tasks such as sending messages or looking for simple information. It was remarked as useless due to its limited function. However, the latest version of Siri has been much improved. It is connected to search engine, maps, and its own server to provide more precise answers. Siri now can tell people a joke (Titcomb 2015), suggest local services/shops and trigger further actions such as making a call for reservation. Cisco's Spark Assistant is another type of VAs. Though it does not work exactly like Siri or Cortana (the VA developed by Microsoft), it also employs artificial intelligence to free users from interacting with physical devices. For the upgraded version, Cisco plans to add features to Spark Assistant so that it can execute more complicated actions such as finding and reserving rooms, proposing relevant materials, recording conversations and taking notes during meetings Finnegan (2017).

According to Finnegan (2017), virtual assistants become more and more popular since Apple Siri, Google Assistant, Microsoft Cortana, and Amazon Alexa are getting better at quickly retrieving information and organizing stuff. From the information architecture point of view, VAs create a new chapter in search. If desktop browsers retrieve search results globally, VAs focuses on local search (Lam 2018b). It provides contextual results so that users can quickly find their desired service/shop close to them. For example, when a person asks Siri for "Japanese Restaurant", Siri will understand that it needs to look for a physical restaurant within that person's area. Thus, Siri automatically puts the keywords "Japanese Restaurant" + "near me". It then displays results with distance, map, opening hours. It even triggers further action by showing the phone icon for calling that restaurant (Figure 5).

López et al. (2017) conducted a study to compare the strength and weakness of the four intelligent VAs (Figure 6). The result reveals that Siri won the prize for the most correct VA while Google Assistant is the leader in natural response. On top of that, it reflects a vast variety of functionalities of the current VAs. They can assist people from shopping to travel, entertainment, administration, conversion, translation, etc. Additionally, VAs are not only implemented in mobile phones but also gain popularity of smart-home devices such as Apple HomePod, Google Home, and Amazon Echo/Alexa. They can even control other appliances and work as a home automation system.
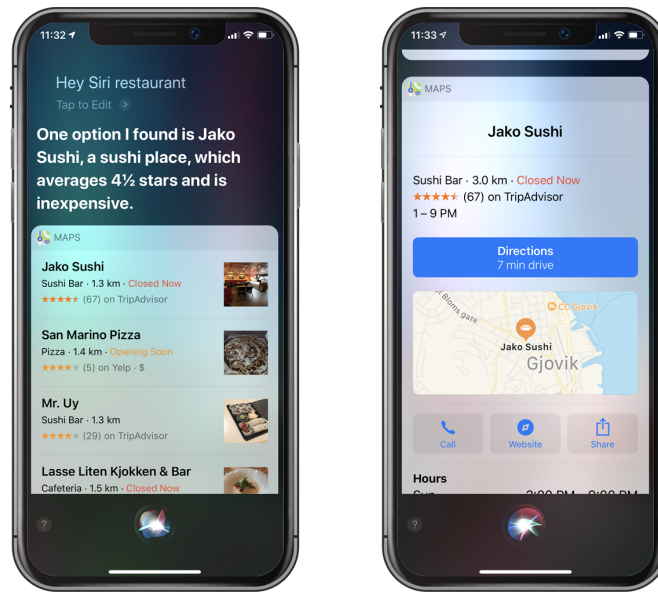
Figure 5: Apple's Siri triggers further action after retrieving information

Feature	Best		Worst	
	Correctness	Naturality	Correctness	Naturality
Shopping and buying assistant				
Introductions	S	GA	C	A
Managing shopping lists	C	A	GA	GA
Shopping online	A	A	S, C, GA	S, C, GA
Finding restaurants	C, GA	C	A	S
Store schedules	C	C	S	GA
Travel and entertainment assistant				
Sport updates	A, S	S, C	GA	GA
Movie info	C	S, GA	A	C
Transportation info	S	A	GA	C
Transportation time	GA	GA	A	A, S
Identifying a song	C	C	GA	GA
Administrative assistant				
Alarms and timers	A, S, GA	A, S	C	C
Managing to-do lists	A	A	GA	GA
Reminders	S, C	S	GA	GA
Reminders in a date	C	C	GA	A
Schedule a meeting	C	C	GA	GA
Compose an email	S	S	A	A
Miscellaneous				
Local news	C, GA	GA	S	S
Traffic updates	C	C	GA	GA
Weather forecast	A, S, C, GA	S	N/A	C
Device management	A	A	GA	GA
Games	GA	GA	S	S

Feature	Best		Worst	
	Correctness	Naturality	Correctness	Naturality
Random (coin)	GA	GA	C	C
Random (dice)	A, S, C, GA	GA	N/A	S
Random questions	GA	GA	S	S
Random facts	S	GA	C	A
Conversions	GA	C, GA	A, S, C	S
Measurements	C, GA	S, GA	A	A
Currency	A, S, GA	GA	C	C
Holiday information	GA	GA	C	C
Calculate tips	GA	GA	A	A
Math problems	S, C, GA	GA	A	A
Time zones	GA	GA	C	C
Jokes	GA	C	S	S
Beatbox	GA	GA	A	A
Translation	GA	GA	A	A
Word definitions	A	A	S, C, GA	S, C, GA

Figure 6: The comparison of personal assistants by features. S = Siri, GA = Google Assistant, C = Cortana, A = Alexa. Source: (López et al. 2017)

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In fact, the primitive stage of VAs has passed. Though they are far from perfection and there are still many aspects that need to be improved, today VAs can perform amazing things as in science fiction. For instance, Google's virtual assistant, Duplex, can make "eerily lifelike" phone calls for booking appointments with natural human's voice and reaction. It includes "er", "mmm-hmm" as a real person that listeners do not aware that they are talking to a machine. When a staff informs that the booking time is not available, Duplex can even respond contextually by suggesting another time slot (Solon 2018). Mark Zuckerberg, Facebook CEO, has brought a science-fiction character to life. He is inspired by the intelligent virtual assistant, Jarvis, in the Iron Man movie and challenges himself to develop a personal smart home assistant (Heath 2016). Mark succeeds in building his own Jarvis Server that can control the main appliances such as lights, doors, toaster, cameras, thermostat, etc. Mark's Jarvis incorporates face recognition, speech recognition, and language processing (Figure 7). Thanks to that, it can execute complicated actions. For examples, to scan visitors' faces and let them access through the main door; to play music based on Mark or his wife's preferences, depending on the person who orders; to chat and perform assigned tasks through the Messenger app (Figure 8). Thanks to continuing advanced technology, the current VAs show unlimited capability of assisting people in every aspect.
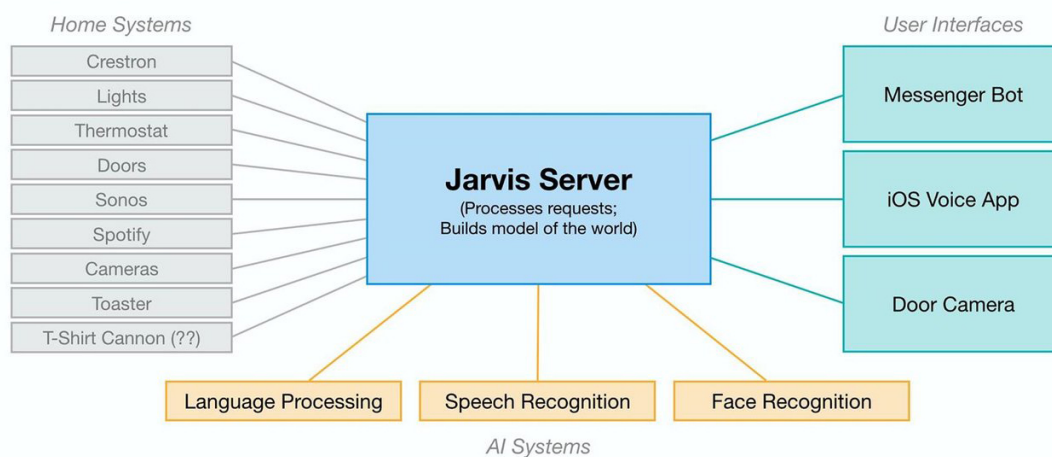
Figure 7: Mark Zuckerberg's intelligent virtual assistant system. Source: (Heath 2016)

Figure 8: Jarvis chats with Mark and performs tasks. Source: (Heath 2016)

2.2.2 How Does Virtual Assistant Resolve Information Overload?

Human being has departed from the past when "information was only accessible to monks in abbey libraries" (Rosenfeld et al. 2015). Since the Internet appears, people all over the world are able to approach boundless information. However, this is a double-edged situation as at the same time, users face the problem of information overload. It is the situation when users have to perform their tasks and keep track of related information sources among the mess of data environment (Klusch 2001). The term "information highway" is entitled to describe the explosion of computer-based tasks and services. Maes (1995) comments that this complicated situation requires a new style of human-computer interaction. In response to this issue, Klusch (2001) suggests "information assistant" as a solution for managing data from the Internet. This is the synthesizing technology comprising methods and tools from several fields such as artificial intelligence. An ideal information assistant should have three characters. Firstly, "information acquisition and management" - it is responsible for retrieving, extracting, analyzing, and keep track of sources. It will also update relevant information on behalf of its users. Secondly, "information synthesis and presentation" - it will encompass varied information, and bring users go through the information space with ease by visualizing and systematic guiding. Thirdly, "intelligent user assistance" - it is able to modify according to changes from users' preferences, and provides intelligent interactive assistance to support users in accomplishing their tasks. Though this information assistant model does not include the workflow (STT > Logic Engine > TTS) as the current VA, it shows the potential of organizing information which could be employed to VA.

It may also be noted, one of the challenges in user interface design for mobile apps is that the similar amount of information displayed on desktops has to be squeezed in palm-sized screens. In addition, that amount of information on small screen keeps increasing since we are living in an information-rich society. It leads to the problem called information complexity. Human visual system becomes intensive since information is mostly transferred through the eyes. To reduce

the superabundance on the sight, Benyon (2014) recommends to apportion to other senses - "key information could be presented in sound in order to free screen space" (p.295). In fact, sound is practical for calling for attention and communicating important messages. Sound is also turning to be the dominant part of "interface design in both mixed reality and multimodal systems" (p.294). Since VA is equipped with Speech-to-Text and Text-to-Speech Engines, it is able to reduce the plenitude of information exposed to the human visual system. Together with the capability of organizing information, there is a basis for confidence that VA is qualified to resolve information overload on user interfaces.

2.2.3 How Does Virtual Assistant Impact the Effectiveness of the Interaction? Applications That Successfully Deployed Virtual Assistant to Resolve Specific Problems

Effectiveness can be defined in varied ways. In HCI design principles, it relates to recovery and constraints. Recovery means the system enables users to get back to the previous status and get away from the errors quickly, while constraints refer to preventing people from making serious mistakes. In usability principles, besides the convenience of turning back to the previous decisions, effectiveness is also described as users' competence of performing tasks easily and effectively (Benyon 2014). In this research, effectiveness is focused on the ability of performing tasks and achieve goals.

In an empirical investigation regarding the effectiveness of using intelligent assistants in supporting online learning, a group of researchers concluded that virtual assistant-based eLearning is the powerful tool to fulfil learners' preferences, goals and desires (Xu et al. 2014). In another research, Milne et al. (2010) and her team developed VA based tutors for children with autism spectrum disorders. The VAs employed in this project, named as Thinking Head, are able to adjust its facial expressions. They are generated to teach children social skills - conversation skills and dealing with bullying. The results showed that most participants gained improvement from pre-test to post-test; averagely, 32% enhancement for the conversation tutor and 54% for the dealing with bullying tutor. Besides, the system is proposed to be used at homes and schools by the participants and their caregivers (Figure 9).
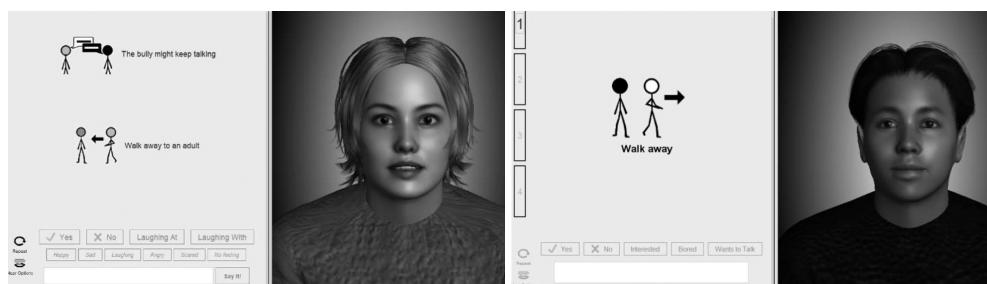
Figure 9: Virtual assistant-based tutors for Children with autism spectrum disorders. Source: (Milne et al. 2010)

Another case study from Priest (2019) reveals that conversational artificial intelligence (AI)/virtual assistant has been applied widely in the public sector in Nordic countries. Based on the fact that residents usually encounter problem in finding information on government websites due to the ineffective search function or obscure words, many municipality websites employ the VA called Kati (or Kari, Kiri, or Karin depending which Nordic country it is used) as a chatbot (Figure 10). This feature provides people with clear and quick answers 24/7. In addition, applying VA to the system also helps the local governments acknowledge the specific population's needs; thus, relevant services are supplied. Consequently, the VA has continuously produced high value:

- 90+ municipalities in the Nordics employ conversational AI
- Kongsberg municipality receives fewer calls to its customer care center by 30%
- Finnish Immigration Service gains 300% ROI in six months
- Finnish Immigration Service also gets 50% reduction in calls
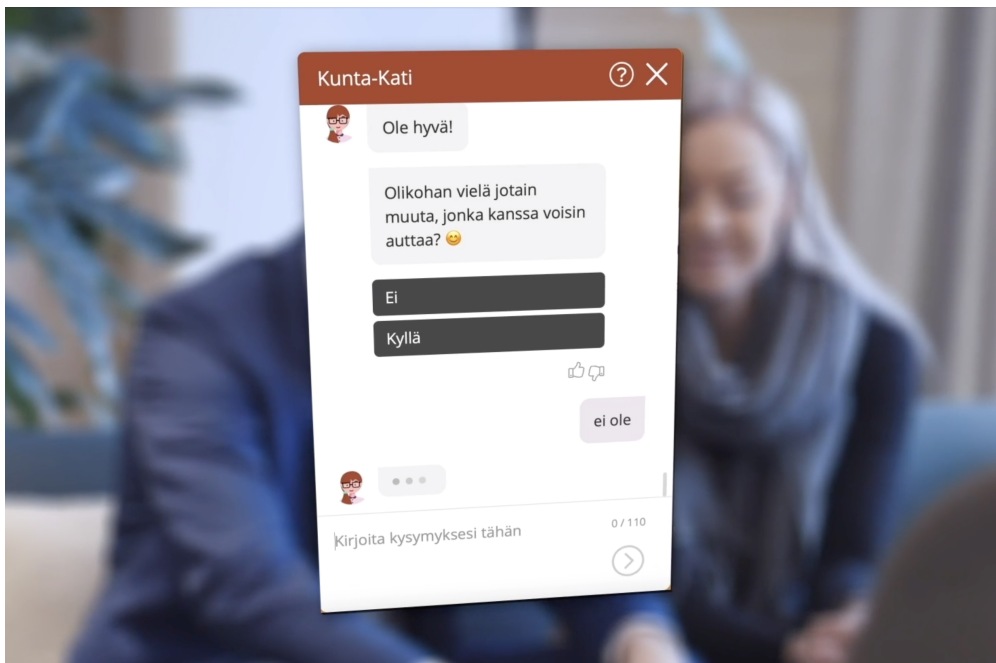
Figure 10: Kati - the virtual assistant that works as the chatbot on a municipality website. Source: (Priest 2019)

It shows that VA is employed universally in various fields, both private and public sectors, and in different interactive systems. It can assist not only the majority of residents but also the specific vulnerable people. VA provides easy and convenient ways to perform tasks, and thus, users can achieve their goals more effectively.

2.2.4 Does Virtual Assistant Improve Engagement in the Human Computer Interaction?

In her paper, Baylor (2009) discusses the importance of an appropriate voice in establishing and prolong the relationship between a VA and a user. Yaghoubzadeh et al. (2013) conduct a study regarding Virtual Assistants as daily helpers for elderly or cognitively impaired people. They learn that a relational VA dialogue system could be a social companion for the elderly. When interacting with it, the elderly is free to select their desired topics for the chats. The VA can also response to long speeches from elderly patients suffering from dementia. These patients show their willingness "to be engaged in conversations with the system". The results reveal that both groups, the elderly and the younger cognitively impaired people, show interest in voice conversations interaction with the VA; especially, the elderly prefer the voice-based interaction modality since they do not acquaint themselves with technology.

However, to enhance the rapport, "it must be seen, not only heard" (Baylor 2009). The voice alone is not enough to magnify the influence of a VA since human beings connect with the world by multisensory. Sound and visual should come together to reinforce the message and enrich the communication. Moreover, the employment of "intelligent user interfaces like believable, life-like characters" strengthens not only the credence from users to the VAs but also the information that being transferred (Klusch 2001). Yaghoubzadeh et al. (2013) and his team develop a prototype, daily assistant Billie which includes humanlike presence (Figure 11), to aid the patients and the elderly in arranging and following a day activity. The experiment endorses positive social effects of a virtual humanoid assistant.

Figure 11: Daily assistant Billie. Source: (Yaghoubzadeh et al. 2013)

The visual presence of a VA is vital, it adds values and brings assistant-based interaction to another stage of fascination. More and more research related to embodied conversational assistants are being explored. The appearance design and behaviours of VA are also considered since

these elements affect the engagement between VA and users. Researchers in this field comment that a VA with "talking head" initiates a new era in human-computer interaction (Cambridge-University 2013). People tend to trust the VA more and they have the emotional engagement with the VA (Benyon 2014). The earlier study from Johnson et al. (2000) demonstrates that animated pedagogical assistants engage and motivate students in the educational environments. Though there are some technical issues, it is proved that having a character involved generates positive experience. To sum up, there are plenty of evidences supporting the concept of visible virtual assistants as they enhance the interacrion by not only voice but also the appearance. In this research they are named as Tangible Virtual Assistants (TVAs).

With specific look, TVAs make a step closer to become the users' companions. Benyon (2014) suggested to focus on "companions" in the HCI as it produces emotional engagement. This means TVAs have to immerse in conversations with users, generate pleasure by entertaining him/her, and provide aids "in whatever format is suitable". By this way, the interaction between users and TVAs turns into a relationship; at the same time, people experience the "richer and more fulfilling interactions". There are several elements converting interactions into relationships which are utility, form, social attitudes, personality and trust, and emotion. Figure 12 illustrates the model of designing for relationship. This model manifests that with those characteristics, TVAs would improve engagement in the HCI.
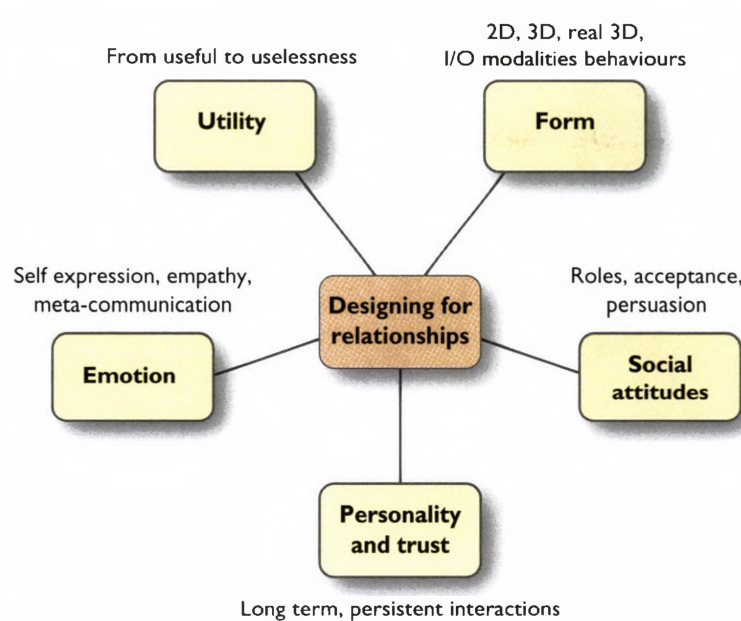
Figure 12: Turning interactions into relationships model. Source: (Benyon 2014)

2.2.5 Can Virtual Assistant Be Employed to Augmented Reality? If Yes, How Will It Affect the Augmented Reality Experience?

The set of tasks or applications that VA can support users is virtually (Maes 1995). The developed VA can be applied in various fields due to its extensibility (Kuznar et al. 2016). VA fulfils different users' needs by impersonating in a variety of personas: as tutors in teaching systems or to clarify the complexities of a new software, as reminders that keep us to date, as monitors that watch over the mail and push notifications, as collaborators that solve problem with people, as surrogates that represent us at meetings (Benyon 2014). Moreover, the employment of VA makes the interactions simpler, especially to people who have limited technical experience (Kuznar et al. 2016). Also, it is convenient that users can approach VA anywhere anytime through mobile apps. Zach Gibson, the chief innovation officer at USAA, comments that VA will be extended beyond the current intelligent speakers and smartphones to function on all devices and probably everything (Crosman 2018).

Nevertheless, there is almost no existing AR app employing VA at the time of this research conducted, except for the AR Google Map which was introduced as a demo video at the I/O developers conference 2018 (Kanter 2018). During the event, Aparna Chennapragada, Google Vice President, presented the AR Google Map with an exciting feature. The app promotes a cute orange fox that works as a guide. The fox helps people to navigate direction and brings more joy. This presentation receives so much cheer and applause from the audiences. Figure 13 shows the virtual fox in AR Google Map.
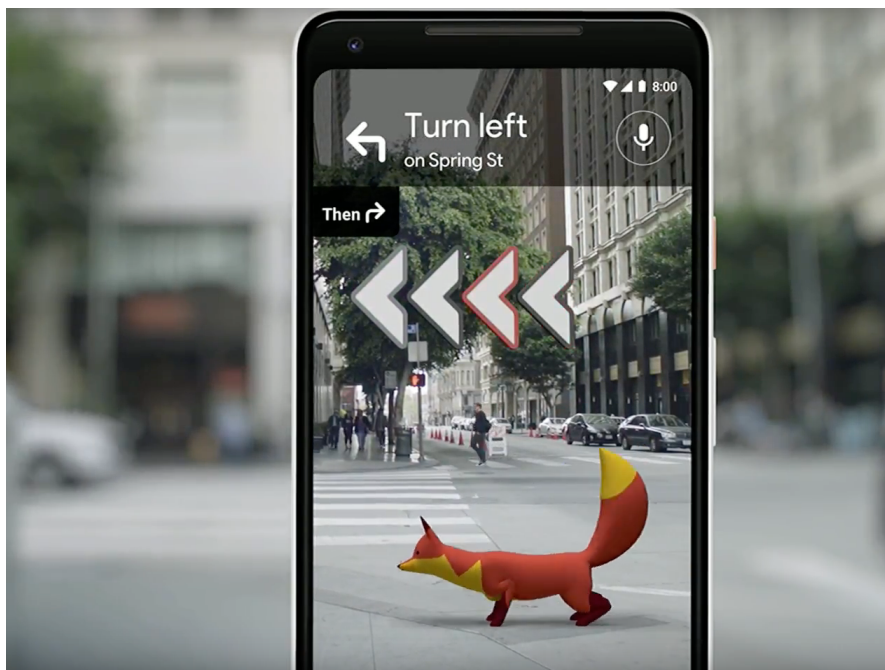
Figure 13: The fox appears as a virtual assistant in AR Google Map. Source: (Kanter 2018)

AR Google Map not only demonstrates the potential of VA employment in AR but also the flexible appearance of a VA. It needs not always with a human look; it could be an animal or any life-like character. To visualise what the appropriate look that could be applied, Benyon (2014) suggested metaphors from real-life assistants to consider what a virtual assistant can do. For instance, we are used to see a personal trainer guiding people step by step to perform a gym machine in training centers. If a VA enacts the personal trainer in an AR app, it could appear as a polar bear. A chubby polar bear teaching people how to get fit is joyful and engaging.

2.3   Hypotheses

Existing literature reveals promising capabilities of VA in various interaction systems. The following hypotheses assert the potential of VA in improving the usability and user experience in the augmented reality environment:

- **Hypothesis 1:** Virtual Assistant simplifies the Augmented Reality user interfaces (reduces information overload).
- **Hypothesis 2:** Virtual Assistant in an Augmented Reality app helps users to achieve their goals more effectively than a standard Augmented Reality app which contains only graphic elements.
- **Hypothesis 3:** Virtual Assistant will enhance the engagement between users and an Augmented Reality app.

An experiment is planned to execute. It will include two sets of the AR app (one as a standard AR app with graphics element only, and one with a virtual assistant). The designs will be tested to compare their differences as well as to examine the hypotheses. In the next parts - Chapter 3, I will describe what methods are used for the study; and in Chapter 4, I will present the technique of developing the design concept.

3 Methodology

In this chapter, I describe what the Method and Research Variables were used for the study; following by the Experimental Design which included the five components: Participants, Tasks, Rating Scales and Questionnaires, Procedure, and Data Collection. Two prototypes, the Graphics and Virtual Assistant apps, were created to perform this experiment. Its development process and functionalities would be presented in detail in Chapter 4. At the end of this chapter was the Ethics part; it explained how this research was conducted ethically and legally under the Norwegian's law.

3.1 Choices of method

The hypotheses in section 2.3 suggested Virtual Assistant (VA) as a new and functional feature for better user experience (UX) of augmented reality (AR) apps. Therefore, to examine those hypotheses, one of the common ways was to compare two AR apps, one with VA and the other one without it.

According to Tullis & Albert (2013), it was important to decide how the data would be used before planning a study. There were two ways to use UX data: formative and summative. Formative study focused on finding the problems of a product/design while it was being created, then improved it to make the final product near to perfect. Summative study aimed to evaluate how well the product/design was, and usually it was employed to compare between products/designs. In this case, summative study was a proper plan. Two prototypes/designs would be created and compared with each other - one employed VA and the other one contained graphic elements only.

Tullis & Albert (2013) also listed ten types of usability studies and recommended the right metrics for each case. In the scenario of comparing products (or prototypes as in this study), he suggested the four metrics could be used: (1) Task success, (2) Efficiency, (3) Self-reported metrics, and (4) Combine & comparative metrics (Figure 14).

Usability Study Scenario	Task Success	Task Time	Errors	Efficiency	Learn-ability	Issues-based Metrics	Self-reported Metrics	Behavioral & Physiological Metrics	Combined & Comparative Metrics	Live Website Metrics	Card-Sorting Data
1. Completing a transaction	X			X		X	X			X	
2. Comparing products	X			X			X		X		
3. Evaluating frequent use of the same product	X	X		X	X		X				
4. Evaluating navigation and/or information architecture	X		X	X							X
5. Increasing awareness							X	X		X	
6. Problem discovery						X	X				
7. Maximizing usability for a critical product	X		X	X							
8. Creating an overall positive user experience							X	X			
9. Evaluating the impact of subtle changes										X	
10. Comparing alternative designs	X	X				X	X		X		

Figure 14: Ten common usability study scenarios and the metrics for each (Tullis & Albert 2013, p46)

The performance metrics which included Task success and Efficiency only tell "what" was effective but not "why". Therefore, it was necessary to collect additional data by comprising other methods such as observation, self-reported data, and interview. In this way, I would collect both quantitative data (to acknowledge which prototype worked better) and qualitative data (to explore why users preferred that specific prototype). Mix-methods research required more time and energy, but in return, it brought extra value (Leedy & Ormrod 2015):

- Completeness: research problems and sub-problems would be fully addressed.
- Complementarity: different methods compensated for each other's weakness.
- Resolution of puzzling findings: the numbers yielded from quantitative data needed qualitative data to clarify the meanings and reasons behind it.
- Triangulation: the study's results would be more convincing when both qualitative and quantitative data lead to the same conclusions.

3.2 Research Variables

3.2.1 Independent Variables

Independent variables were the things we manipulated or controlled for (Tullis & Albert 2013). In this study, the independent variable was the UI design which had two models: (1) an AR app with graphical user interface only, (2) an AR app that employed a virtual assistant and minimized graphical information.

3.2.2 Dependent Variables

Dependent variables were the things being measured (Tullis & Albert 2013). In this study, they were information overload, effectiveness, and engagement. These variables were interpreted as below:

- Information overload: happened when information appeared as a hindrance rather than aid, even though that information was potentially helpful (Bawden & Robinson 2009).
- Effectiveness: was described as the "percentage of tasks successfully completed, and percentage of users successfully completing tasks" (Benyon 2014)(p.256).
- Engagement: related to enjoyable user experience integrated by elements of positive affect, aesthetic and sensory appeal, attention, novelty, and interactivity (Obrien & Toms 2008).

3.3 Experimental Design

3.3.1 Participants

Participants were recruited from NTNU in Gjøvik as "convenience sampling" (Leedy & Ormrod 2015). There were 37 people in total including 15 females and 22 males. Most of them, 28 people, were in the age of 20 – 25, 7 people from 26 – 30 years old, and the rest were in 31 – 49 age range. Some of the participants were not sure what the term "augmented reality" was but when I asked them "do you know Pokemon GO game? That is the example of an AR game", everyone responded that they knew it. Simply put, 100% of participants were aware of AR and VA (e.g., Siri, Google Assistant). Recognition of these two concepts was the condition to take part in this study.

3.3.2 Tasks

Participants were given the scenario of being in a big and new supermarket for the first time. They needed to purchase some products but could not find those, and there was no staff around for them to ask. Therefore, they decided to use the AR mobile app to quickly locate their desired items. Participants were supposed to find two products by using two different prototypes. For the Graphics app, the user was required to look for Maarud Peanut product in CoopXtra supermarket. For the VA app, the user was requested to find Gilde sausage in Rema supermarket. After interacting with each prototype, the participant received a Floor plan of the respective supermarket to mark the product's location, then following by the Questionnaires. There were three Questionnaires in total which are Post – Graphics app, Post – VA app, and Post - Study Questionnaire.

To counterbalance the influence as well as the impression of each app towards participants, I switched the order of prototypes between participants. Table 1 showed how it was done.

Order of prototypes		
Participant 01	Graphics app	VA app
Participant 02	VA app	Graphics app

Table 1: Counterbalance of order of prototypes

3.3.3 Rating Scales and Questionnaires

As mentioned in the Choices of Methods 3.1, self-reported was one of the metrics used for "comparing designs" scenario. To collect self-reported data in UX study, questions with rating scales was the common way (Tullis & Albert 2013). However, to create proper questions and rating scales were challenging, it was mixed of art and science. In this study, the questions and type of

rating scale were developed based on the General Guidelines of Tullis & Albert (2013) and were taken reference from Andreas (2013). Three points were considered when I created the content for questionnaires:

- The collected data would be more reliable if participants were asked in different ways to evaluate an attribute (e.g., engagement). In the data analyzing process, those responses would be averaged to yield the overall reaction of participants for that attribute.
- The combination of negative and positive questions would reduce bias, and the participant tended to think more carefully before giving the answers.
- There would be a Post – App Questionnaire for each prototype (Graphics and VA), and Post - Study Questionnaire to compare those prototypes. 7-point Likert scales were used for the Post – App while 7-point Semantic Differential scales were applied to the Post - Study. In this case, the pair of bipolar in Semantic Differential scales was "Graphics only" and "VA".

All the questions focused on the three hypotheses regarding information overload, effectiveness, and engagement.

- For the information overload, I referred to the Computer System Usability questionnaire developed by Lewis (1995) and Questionnaire for User Interface Satisfaction developed by Chin et al. (1988).
- For the effectiveness, I took the reference from the Usefulness, Satisfaction, and Ease of Use (USE) questionnaire developed by Lund (2001).
- For the engagement, I picked some questions from the USE questionnaire and the well-known question from the Net Promoter Score (NPS) originated by Reichheld (2015) - "How likely is it that you would recommend this product/design to your friends and family?" This question aimed to measure engagement based on customer loyalty. Different with the respondent answer from the NPS which using 11-point scale, I used the 7-point scale so that it was consistent with the rest.

The Post – Graphics app (Appendix A.4) and Post – VA app (Appendix A.5) had similar questions; however, there were additional four questions to the Post – VA app regarding the full-body VA (Table 2). The Post - Study questionnaire had six questions relating to preferences between the Graphics app and VA app (Appendix A.6).

	Post – Graphics app	Post – VA app
Information Overload	5 questions	5 questions
Effectiveness	3 questions	3 questions
Engagement	4 questions	4 questions
Full-body VA		4 questions

Table 2: The structure of questions in Post – app questionnaire regarding different characteristics

In each question, the keywords were capital so that participants could understand them easily by just skimming through. At the end of every question was the optional comments for users to elaborate on their answers. This was also for me collect qualitative data which would be used to interpret "why" after "what". Figure 15 was an example of the Post – Graphics/VA app question-

naire, and Figure 16 was one of the questions of Post - Study questionnaire.

Figure 15: Questions of the Post – Graphics/VA app questionnaire

Figure 16: Questions of the Post – Study questionnaire

3.3.4 Procedure

To make sure all participants would receive the same information, I created a protocol and listed the order of tasks to be given to participants (Appendix A.1). Before conducting the actual experiment, I run pilot tests with four people. Two of them received the Floor plan tasks while the other two did not. This arrangement helped me to decide if the Floor plans should be used in this study. Thanks to the pilot tests, I recognised some parts needed to be fine-tuned; also, some questions were rephrased to avoid misunderstanding. I decided to use Floor plans in the actual test as well. In the Floor plan task, participants could watch the clips again if they were not sure where the product's location was because this task did not aim to test their memory but to find out if the prototypes helped users to navigate and pinpoint positions correctly.

The experiment lasted for two weeks from 10:00 – 17:00. This duration allowed me to fulfil the number of participants I expected. At the examination, each person received the warm welcome and compensation for their participation. They were also informed about the rights and data privacy according to the NSD (Norsk Senter Forskningsdata). Table 3 described step by step was conducted with a participant (the design of the two prototypes would be described in Chapter 4. The below procedure was performed after the prototypes had been executed).
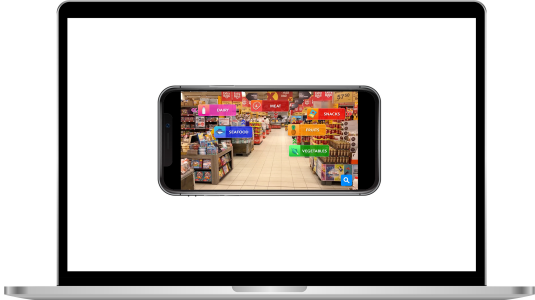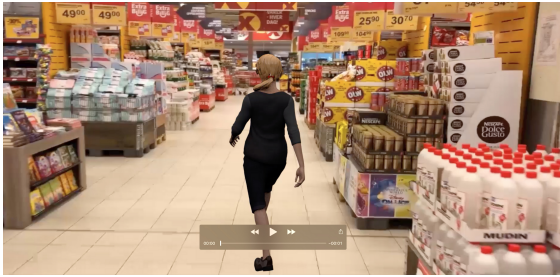
Participant 01	
Step 01	Briefly introduce about the project
Step 02	Hand over Consent form (Appendix A.2)
Step 03	Summarise of what were the tasks and how many questionnaires a participant was supposed to complete
Step 04	The participant to fill in Demographic Survey (Appendix A.3)
Step 05	Show the image of Maarud peanut and requested the participant to look for this product with the first prototype
Step 06	Open the Graphics prototype in Keynote (MacBook)
Step 07	When the first scene was shown on the screen, I asked the participant "what are you going to do to find Maarud peanut?"
Step 08	Depend on what the participant said where he/she would like to tap on, I used mobile phone as the remote control to operate this Wizard-of-Oz prototype
Step 09	After he/she had done with the first prototype, I gave him/her the Floor plan (Appendix A.7) of Coop supermarket to mark the product's position
Step 10	The participant answered the Post – Graphics app Questionnair
Step 11	Show the image of Gilde sausage and requested the participant to look for this product with the second prototype
Step 12	I launched the VA prototype and asked the participant "what are you going to do to find Gilde sausage?". Similar to the first prototype, I used my phone to control until the participant finished his task
Step 13	Gave him/her the Floor plan (Appendix A.8) of Rema supermarket to mark the product's position
Step 14	The participant answered the Post – VA app Questionnaire
Step 15	Show the participant the short clip of full-body VA before he/she answered the last 4 questions. (Click here for the video)
Step 16	The participant to answer the Post - Study Questionnaire
Step 17	A short interview – the participant was asked to share his thoughts/comments regarding the two prototypes

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Table 3: Step by step of the experiment process

3.3.5 Data Collection

To compare the two prototypes, I collected several different types of data. The quantitative data were accumulated through users' responses to the questionnaires. The Post – App (Graphics and VA) questionnaires' scores were gathered by Google Form, while the Post – Study questionnaire's scores were collected from papers. The reason for this was that Google Form did not provide the option of displaying (-3 -2 -1 0 1 2 3) grading scale in the answers. Hence, I had to give participants printed papers and then converted them to digital data after that. The qualitative data were compiled from users' comments below each question, and my notes when I conducted short interviews with participants. In addition, to measure the task success on the Floor plans, I collected the users' answer sheets at the end of each session. The outcome was evaluated based on (1) the user marked the product's position wrong or right, and (2) the user watched or did not watched the clip again.

3.4 Ethical and Legal Considerations

To avoid probable bias, I had gone through discussions with my supervisors before the experiment was conducted. Bias could come from the questionnaires, the conversation between participants and me (as a researcher), the design of both prototypes, the procedure of the experiment, etc. By preventing possible bias, the research would obtain valid results; and thus, its findings would be meaningful.

Besides, I contacted the NSD (Norwegian Centre for Research Data) to inform about the project, as well as submitted relevant document to get approval for the research experiment. NSD required researchers to declare what types of participants' data would be collected, how it would be stored, protected, and analysed; how participants would be informed regarding their rights and confidences, etc. After receiving approval from the NSD, I downloaded the Consent Form (Appendix A.2) and distributed it to participants before the experiment. This Consent Form contained my project details and informed participants their rights such as they could withdraw anytime, personal data would be kept under privacy, the visual document that included participants' face would be censored, and so on.

Also, all participants in my experiment were given corresponding code numbers so that nobody could recognise their names, even my supervisor when he worked with me on the data analysis. This set of actions confirmed that my materials and activities in the study were ethical and legal under the Norwegian's law.

4   Designs and Executions

This chapter describes the design process of the two prototypes which would be used for the user study planned in Chapter 3. It started with developing the design concept; and then, the execution of the user-centered prototypes.

4.1   The Journey of Developing a Design Concept

4.1.1   The Double Diamond Model

To get an idea of what kind of augmented reality (AR) mobile app to be developed was the very first challenge. I talked to someone to find out what were the problems they had encountered in their daily lives and wished to have better solutions. For instance, one of my colleagues from Vivaldi said that he liked refurbishing his house and looked for an app which could show him in advance how the room would look like when being painted in different colors, or where decorative items and furniture could be placed. It sounded interesting, but somehow, it was similar to the AR app that IKEA had launched before (*IKEA Place augmented reality app* n.d.). In fact, I thought of developing a mobile app which not only to test the hypotheses but also to create an entirely new concept for practical use.

My exploring journey was inspired by the Double Diamond model - the creative design process developed by the British Design Council (Figure 17) (*The Design Process: What is the Double Diamond?* 2018). This model guided designers through the Discover and Define stages (to confirm the problem definition) before moving on to the Develop and Deliver phases (to create the solution). Thanks to it, designers would come up with the proper solution for the exact problem instead of spending time and effort on solving the wrong problems.

Looking for a design concept was an exploring journey with my sketch diary. I noted all the problems and possible ideas which can be applied. When I was in a gym room, a friend of mine asked me how to use some of the machines there. I was thinking of why not creating an app that guides people to use training machines. A virtual assistant, in this case, could be a polar bear. Imagine how fun it was when a chubby bear was guiding people how to get fit (Figure 18).

However, to create the 3D polar bear animation was beyond my competence and why people must use AR in this case while they could simply watch a video. An AR app was only functional and practical when the situation demanded supplementary virtual information added to the physical world. On another day, I was in a supermarket and looking for a sauce; I knew that I was in the right area where all the seasonings and spices were located. Still, more than ten minutes walking back and forth, I could not find that specific sauce. I realized it was a common problem which could happen to anyone. Perhaps I should employ AR and VA to solve this pain
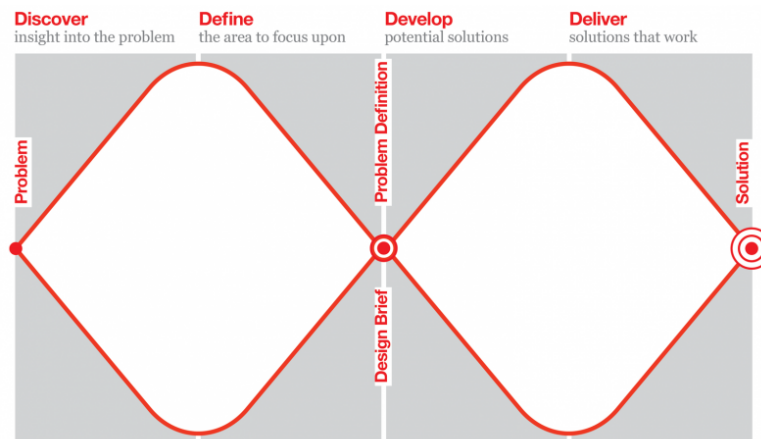
Figure 17: The Double Diamond design process model. (Source: *The Design Process: What is the Double Diamond?* (2018))

point. A quick online survey was conducted to explore what were the other issues that people encounter when shopping in supermarkets. This study was part of the IMT4882 Specialization Course II IMT4882 (Lam 2018*a*).

The survey was aimed to discover shopping behaviour; and more importantly, to find out possible problems that people encounter in supermarkets. This early user-testing was the vital step to generate an effective AR app that responded to exact users' needs. The result found that 53% had an issue with finding their desired items, while 30% could not spot the items' price, the other 30% felt it was hard to recognise which brand offered lower price among the same type of product (Figure 19). According to the survey, "Cannot find the items that I want" was the significant problem. Some people responded that they would "find an alternative item or skip it" or just leave the store. This major issue frustrated customers; at the same time, it negatively affected the sale of supermarkets and the brands which carried those concealed items. For that reason, I aimed to design the AR app that solved the problem of "cannot find items".

Figure 18: Polar bear as a virtual trainer. (Image sources: (1)The bear image, (2) The gym room image)

What problems do you usually encounter when being at a supermarket?

13 responses
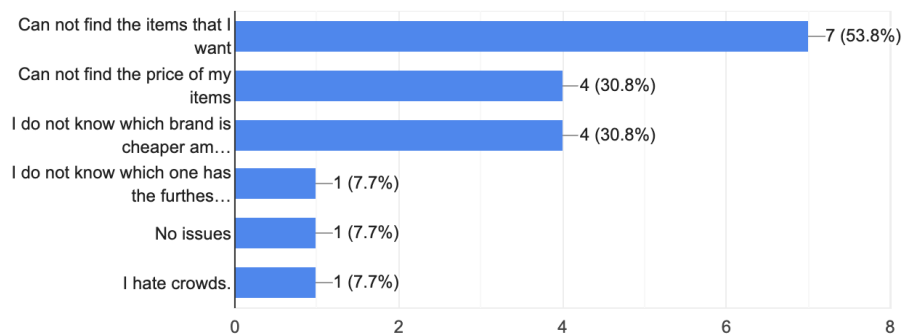
Figure 19: Issues of shopping in supermarkets

The scenario for this design concept was that a person visited a big and unfamiliar super-market for the first time. She intended to buy different products such as minced meat, canned food, cheese, jam, and hand cream. These items were in various areas since they were different types, which were fresh meat, canned food, dairy, and personal care. Finding those products in the unacquainted supermarket consumed much time. The purchaser was in a hurry; therefore, she decided to use the AR app to locate those items quickly.

4.1.2   The Physical Supermarket Model

To execute the design concept, initially, I thought of building a physical supermarket model with cardboards and required participants to find assigned products by using the AR mobile app. By creating this scene, the experiment reflected the actual situation so that users would interact with the prototypes as if they were in a real supermarket. To implement this idea, I would need to set up an imitation supermarket and develop the AR app that really functioned.

For the supermarket mock-up, its shelves would have equal size and height with actual supermarket's shelves. Products' packages were planned to collect, placed on the shelves, and located in different categories as the way they were displayed in reality. Figure 20 illustrated how this supermarket model would look like.

Figure 20: The initial physical supermarket model planned to build

For the AR app development, I looked into the document of ARKit – Augmented Reality for iOS Apple (2017). After many days of trying to understand it, I realized that it was impossible for a designer who had no knowledge of programming language to use this platform. I was eager to create something fascinating and high-tech, but there were too many limitations to turn this idea come true. Perhaps, finding another solution was the right way instead of investing time on an entire new realm. Finally, I decided to employ Adobe After Effects to convey the AR experience to my users. The next section explains how different design software was applied to create the AR prototypes.

4.2   User-centered Prototype Design

4.2.1   Overview of the UX/UI Design and Implementation

As mentioned, After Effects was chosen as the main instrument to execute the AR experience prototypes. My plan was to utilize the Wizard-of-Oz method (Kelley 1984). Firstly, I would need to prepare all the design materials (e.g., elements for the graphics and virtual assistant user interface). Then, I applied After Effect to build the prototypes and exported them to videos. Thereafter, I employed Keynote (a presentation software in MacBook) to display the videos as AR apps in front of participants, and I used my phone as the remote control to operate these apps.

To make sure both prototypes were created with equally appealing and ease of use, several general design guidelines were referred and applied to the UX/UI design process, they included: *Laws of UX* (n.d.), 10 Usability Heuristics for UI Design (Nielsen 1994), and Google *Introduction - Augmented Reality Design Guidelines* (n.d.)

4.2.2   The Graphics Prototype

This Graphics prototype had been explored and initially developed in the Specialization Course II IMT4882 (Lam 2018*a*). Similar to the Gestalt Principles of visual perception, in augmented information organization, related objects were grouped in a way that users could recognise them intuitively (Singh & Singh 2013). On the first screen, it displayed a group of labels which inform users the location of different categories. These labels contained icons and texts to identify different types. Each icon represented a particular category. For instance, the Dairy label included a milk bottle icon, the Seafood label contained a fish icon, and so on. They were also distinguished by color, pink for dairy, red for meat, green for vegetables, blue for seafood, etc. (Figure 21). As well, the label size was considered so that it was big enough for readability, but not too large that occupied the screen space and blocked the reality. The virtual labels placed on screen were aligned with the actual location of the supermarket's category. For instance, the Vegetable label in the AR interface corresponded to the vegetable section of the supermarket. Besides the virtual labels, the app also included a search icon for users to key in a specific product name (e.g., Nyco Omega 3)
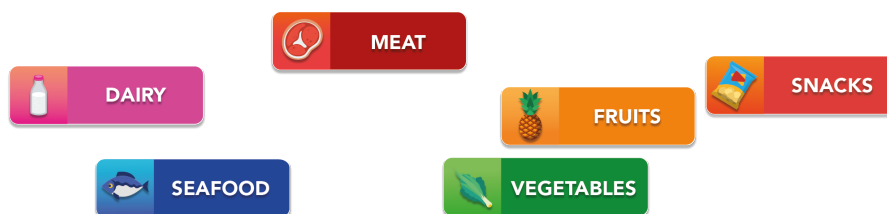
Figure 21: Virtual labels to be overlaid on the supermarket scene

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If users tapped on a label, Meat for example, the app displayed navigational arrows to show users the way to that area. Nunes et al. (2017) recommended to apply 3D arrows to identify points of interest, the various arrow sizes implied the distances between users and those items. In this prototype, animated arrows were overlaid on the floor, and complied with the perspective rules.

4.2.3 The Virtual Assistant Prototype

At first, I planned to create a full-body virtual assistant (VA) that worked like a virtual staff in supermarkets. Adobe Fuse CC was employed to create the 3D character, and Mixamo was applied to animate it (Figure 22). The character had perfect movement but to transfer it to After Effect for building this prototype was extraordinarily challenging and beyond my capability. It required knowledge, experience, and accomplished skill of 3D animation which involved many design software. Eventually, I decided to employ Animoji from iPhoneX to create my own VA. Animoji allowed me to generate the VA's look with customizable features such as gender, shape of face, skin tones, hairstyles, etc. Especially, Animoji could mirror my facial expressions when I was talking or smiling, and it even captured head movements. My VA character had the look of a young and smart lady which would provide trust to users (Figure 23).

Figure 22: The initial full-body virtual assistant created by Fuse CC and Mixamo

33
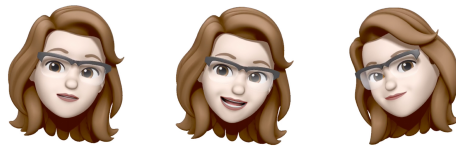
Figure 23: The final virtual assistant's appearance created by Animoji

The next part after VA's appearance was the voice over. Animoji let users record their voice together with the character's motion as a video. Since I was not a native English speaker, I used Animaker to turn text to speech. Also, I adjusted the Speed and Pitch so that it sounded natural and matched with the VA's facial expression (Figure 24).
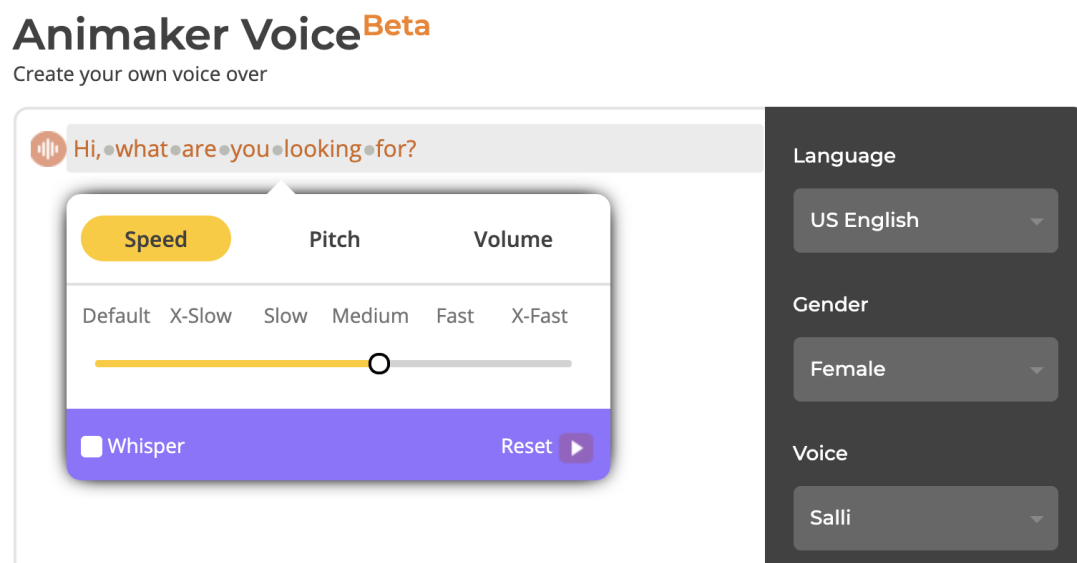
Figure 24: Create voice over for the VA

Following this was Voice User Interfaces (VUI) design phase. When users interacted with a VA such as Siri or Google Assistant, they had conversations not only by talking/listening but also through the UI of the app. Therefore, it was crucial to understand the VUI design concept. I took references from the "Six Principles for Designing for VUI" from Fjord, and VUI — The Ultimate Designer's Guide (Baker 2018). Baker (2018) had described the basic voice UX flow (Figure 25) and commented on the three points that enhanced voice motion experience - Transitory (drives transition seamlessly between different states), Vivid color (evokes delight and futurism which produces engaging interaction), and Responsive (gives users enough feedback and allow them to track the process).
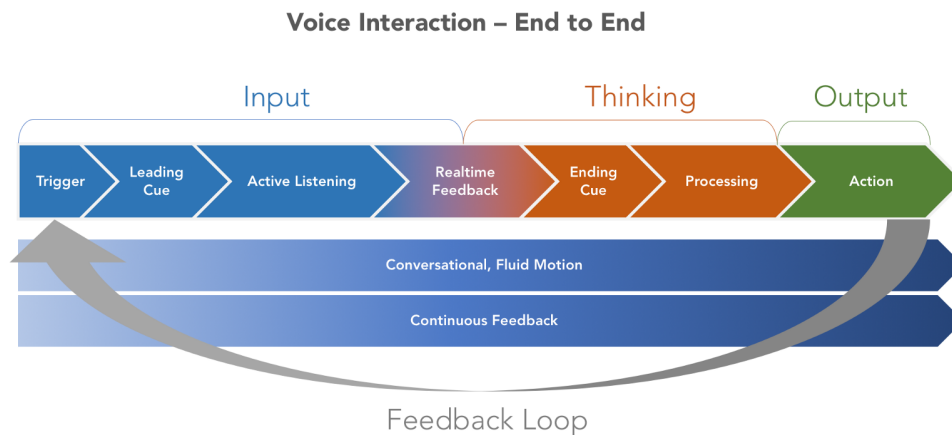
Figure 25: Basic voice UX flow (Baker 2018)

As it was necessary to provide auditory/visual cues to users when the device was listening, I created a slight animation for the microphone icon (Figure 26); also, the animation of showing texts when users were asking the VA for a product (e.g., "Gilde sausage"). The app then displayed real-time texts, giving users the opportunity to correct and affirm actions (Figure 27).

Figure 26: Slight animation showing the app was listening to the user
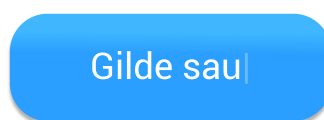
Figure 27: The animation of showing real-time text

In addition, conversational UX was another aspect of voice interaction. The app not only received commands from users but also communicated as a live assistant. In this prototype, the VA replied to a user "Gilde sausage is over there. Please follow me". By giving this affirmative message, VA brought a sense of human-human communication instead of human-computer interaction.

4.2.4   Execution of The Two Prototypes

After creating all necessary design materials for the two prototypes, I visited the two supermarkets - Coop and Rema to record its surroundings which would be used as the background scenes. The two apps had different ways of interaction but similar way of displaying navigation. The Graphics app was designed with animated arrows overlaid on the floor while the VA app had animated directional lines. Besides the directional lines, there was also a full-body VA which worked like a virtual staff. The clip of full-body VA would be shown to participants at the end of the test to find out which one was preferred - animated arrows/lines or full-body VA (section 3.3.4, Table 3, Step 15). (As mentioned above, to transfer a 3D animation character to a video required expert skill; therefore, I had a friend generated this short clip).

Table 4 and Table 5 showed how these two apps operated.

Graphics app

Scene 01: The app displayed virtual banners overlaying the supermarket's scene. (Click here for the video)

Scene 02: If users taped on any label (e.g., Snacks), it brought users to that corresponding area by navigational arrows overlaid on the floor. (Click here for the video)
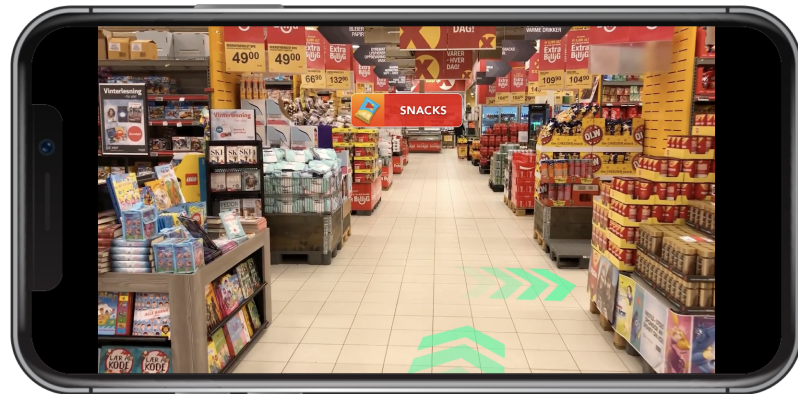
Scene 03: If users taped on the search button on the first scene, it let people input the product name.

Scene 04: If users chose to input a product name (e.g., Maarud peanut), it brought users to the exact location of that product. (Click here for the video)

Table 4: Operation of the Graphics app

37

	Virtual Assistant app
Scene 01: The VA welcomed users with both voice and text "Hi, what are you looking for?". The app provides two options for users to input information – to talk or to type. (Click here for the video)	
Scene 02: The app displayed real-time text when users were talking/writing (e.g., Gilde sausage). (Click here for the video)	
Scene 03: The VA responded "Gilde sausage is over there. Please follow me". The app guided users to the exact location by arrows pointing to the product's area and navigational lines overlaid on the floor. (Click here for the video)	
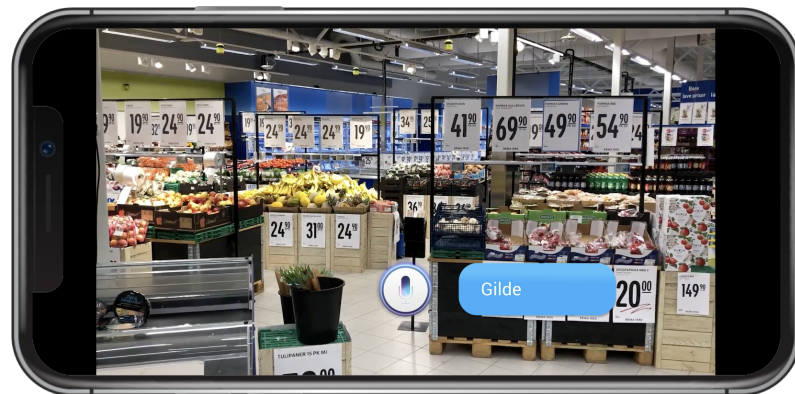
Table 5: Operation of the Virtual Assistant app

These two prototypes were the main tools to perform the experiment, which was planned in Chapter 3. In the next chapter, I delineate the quantitative results of the user study. These results would reveal if the differences between the Graphics and VA apps were significant.

5 Quantitative Results of The User Study

5.1 Overview

In this chapter, I summarised the quantitative results of the experiment into the following sections: Information Overload, Effectiveness, Engagement, Full-body Virtual Assistant, and Graphics Versus Virtual Assistant Preferences. This chapter focused on "what" the results were, while the next section – Chapter 6 would find out "why" it happened that way by going through the qualitative data.

Tullis & Albert (2013) suggested using a paired-samples t-test when the experiment had the same set of participants performed tasks using prototype A and then B, and it aimed to measure variables such as self-reported effectiveness. The key of this paired-samples t-test was to compare each user to themselves; in other words, we were looking at the difference in each participant's data for the Graphics app and VA app. To analyse the data, we used SPSS version 25 and Excel version 16.16.9. SPSS provided details of the t-test values (Appendix A.9) while Excel was employed to compare the means between questions of each dependent variable. Figure 28 presented the overall result of samples t-test. Data regarding the Floor Plan tasks were also analysed. Results showed that more people correctly marked the position of Gilde sausage on Rema's floor plan (using the VA app), but it was not sure because of the independent variable or due to its floor plan design was more straightforward than the other one. As I realized it contained many uncontrolled variables, the results of Floor plan were eventually eliminated.

Paired Samples Test

| | | Paired Differences | | | | | | | |
| | | | | | 95% Confidence Interval of the Difference | | | | |
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2–tailed)
Pair 1	GR_information_overload – VA_information_overload	4,05405	5,16906	,84979	2,33060	5,77751	4,771	36	,000
Pair 2	GR_effectiveness – VA_effectiveness	–2,62162	3,23481	,53180	–3,70016	–1,54308	–4,930	36	,000
Pair 3	GR_engagement – VA_engagement	–,24324	5,66375	,93111	–2,13163	1,64515	–,261	36	,795

Figure 28: Overall result of paired-samples t-test

5.2   Information overload

The Post – Graphics and Post – VA Questionnaires were given to participants after each app session. The first five questions aimed to measure information overload, and participants were asked in different ways to evaluate this aspect. Users responded by selecting one point on the 7-point Likert scale between "Strongly Disagree" and "Strongly Agree". Below was the list of questions regarding information overload:

- Question 01: I feel that there is TOO MUCH information to manage in this app
- Question 02: It was EASY to input the item that I was looking for
- Question 03: The user interface is CONFUSING
- Question 04: The information on the screen is EASY to understand
- Question 05: The organization of information in this app was NOT clear

Figure 29 showed that both apps obtained high scores in all questions, the Graphics app received 5 to 6 points while the VA app gained even higher scores – all were above 6.

Figure 29: The difference of means of each question regarding Information Overload between the Graphics and VA apps (all the scores were converted to total positive scores)

As the questions included negative and positive statements, to calculate the total positive score that each participant gave, I took 8 to subtract the received scores for negative questions, then added the received scores for positive questions all together. The formula could be written as below (Q stands for Question):

The total score of Information Overload given by one participant
= (8 - Q1) + Q2 + (8 - Q3) + Q4 + (8 - Q5)

By applying this formula for 37 participants and took the average of all the values, I got the mean score for each app. Figure 30 showed that the mean scores of both apps were very high: 27,97 and 32,03 over 35 points for the Graphics and VA accordingly. This result indicated that though the Graphics app had a lower point than the VA app, users thought at both apps had clear information organization. Besides, the paired-samples t-test showed that the Information Overload Graphics app (M = 27,97, SD = 5,13) and VA app (M = 32,03, SD = 3,75); t (36) = 4,77, p = 0,00 (Table 6). **It demonstrated that the difference was significant. This value confirmed the VA app was significantly less information overload than the Graphics app.**
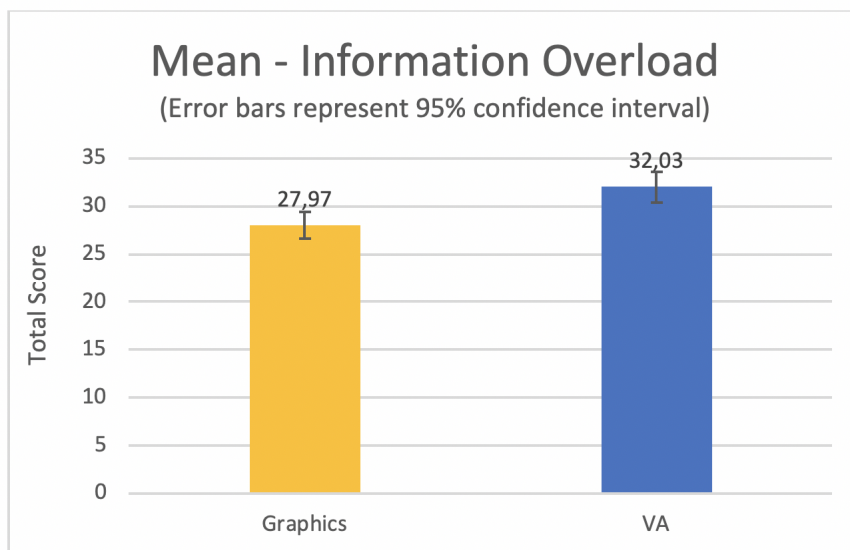
Figure 30: The difference of means of each question regarding Information Overload between the Graphics and VA apps

Descriptive Statistics – Information Overload				
	Mean	t	df	p
Graphics - VA apps	4,05	4,77	36	0,00

Table 6: Descriptive statistics of the Information Overload characteristic

To visualize where the Graphics and VA app stood on the 7-point Likert scale, we divided the total mean score of each app by the total questions for Information Overload (5 questions in this case), we got the average score per question:

Graphics: 27,97 / 5 = 5.59

VA: 32.03 / 5 = 6.40

Score different between 2 apps: 6.40 - 5.59 = 0.81

This meant the VA app was higher than the Graphics app 0.81 point on the Likert scale of (less)

Information overload (Figure 31).
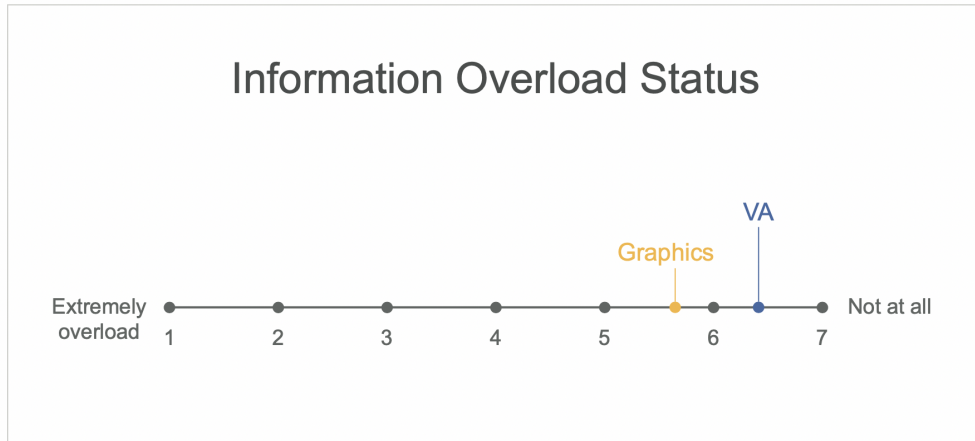
Figure 31: The rank of Graphics and VA apps regarding Information Overload on the 7-point Likert scale

5.3   Effectiveness

Effectiveness was measured by observation on task performance. I noted how users found the products by using the Graphics and VA apps. This information would be discussed in detail in the next chapter - section 6.3. Also, it was measured by three questions in the Post – App questionnaires:

- Question 06: I COULD find the exact location of a specific product using this app
- Question 07: I felt that it was NOT easy to complete the task with this app
- Question 08: I was able to find the item using this app with LITTLE effort

Figure 32 presented both apps obtained high scores in all questions, the Graphics app received 5 points while the VA app gained higher scores – all were above 6.
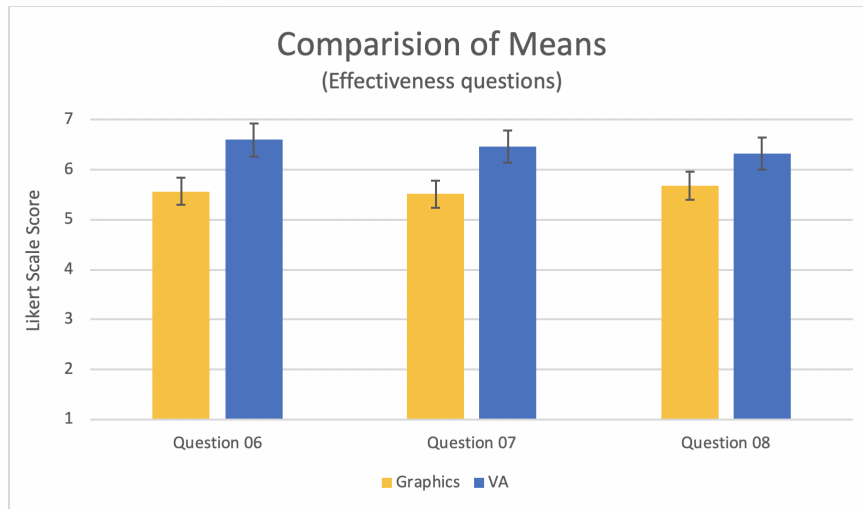
Figure 32: The difference of means of each question regarding Effectiveness between the Graphics and VA apps (all the scores were converted to total positive scores)

Similar to the Information Overload questions which included negative and positive statements, to calculate the total positive score that each participant gave to Effectiveness, I applied this formula (Q stands for Question):

The total score of Effectiveness given by one participant
= Q6 + (8 - Q7) + Q8

Figure 33 presented the mean of Graphics app was 16,76 while VA app was 19,38 over total points of 21. This result revealed that despite the Graphics app had a lower point than the VA app, users thought at both apps were highly effective. Besides, the paired-samples t-test showed that the Effectiveness Graphics app (M = 16,76, SD = 3,95) and VA app (M = 19,38, SD = 2,15); t (36) = -4,93, p = 0,00 (Table 7). **It confirmed the difference was significant. The collected data indicated that the VA app was significantly more effective than the Graphics app.**

Descriptive Statistics – Effectiveness				
	Mean	t	df	p
Graphics - VA apps	-2,62	-4,93	36	0,00

Table 7: Descriptive statistics of the Effectiveness characteristic

To visualize where the Graphics and VA app stood on the 7-point Likert scale, we divided the total mean score of each app by the total questions of Effectiveness (3 questions in this case), we got the average score per question:
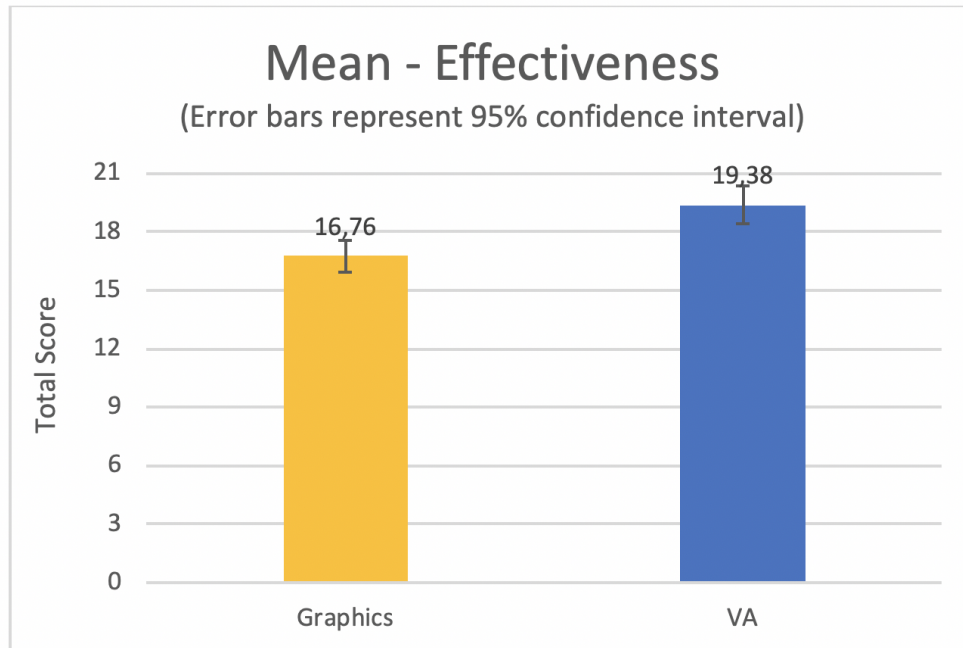
Figure 33: The difference of means of total positive scores regarding Effectiveness

Graphics: 16,76 / 3 = 5.59
VA: 19,38 / 3 = 6.46
Score different between 2 apps: 6.46 - 5.59 = 0.87
This meant the VA app is higher than the Graphics app 0.87 point on the Likert scale of Effectiveness (Figure 34).
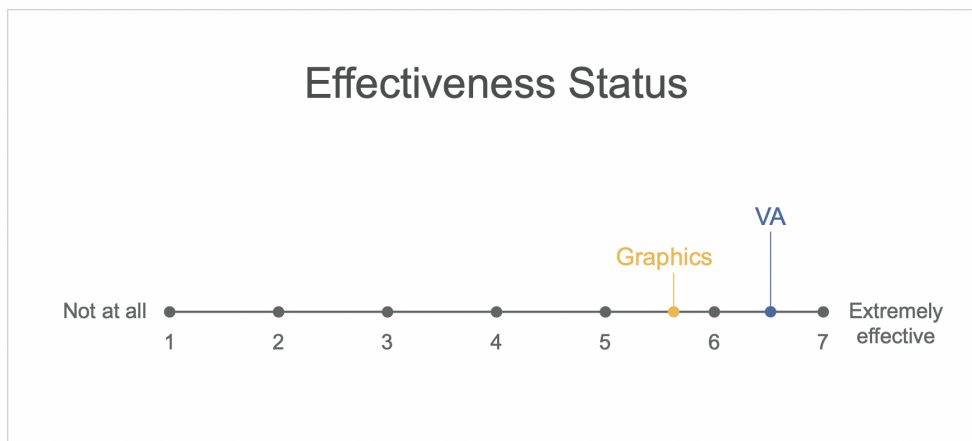
Figure 34: The rank of Graphics and VA apps regarding Effectiveness on the 7-point Likert scale

5.4 Engagement

Engagement was measured by both qualitative and quantitative methods. Qualitative data came from participants' comments and verbal sharing thoughts during the short interview at the end of the experiment. The result of qualitative data would be discussed in section 6.4. Quantitative data was collected from four questions in the Post – App Questionnaires:

- Question 09: I felt this app is NOT fun to use
- Question 10: I WILL use this app in the reality
- Question 11: I do NOT like the interaction way of this app
- Question 12: I WOULD recommend this app to my friends and family

Figure 35 showed that the means of VA app were just slightly higher than means of Graphics app. Different from the rest, VA app had a little lower score than Graphics app in Question 10. Why more users chose to use Graphics app in reality while they leant to VA app in other responses? The reasons for this would be revealed in the next chapter, section 6.4.
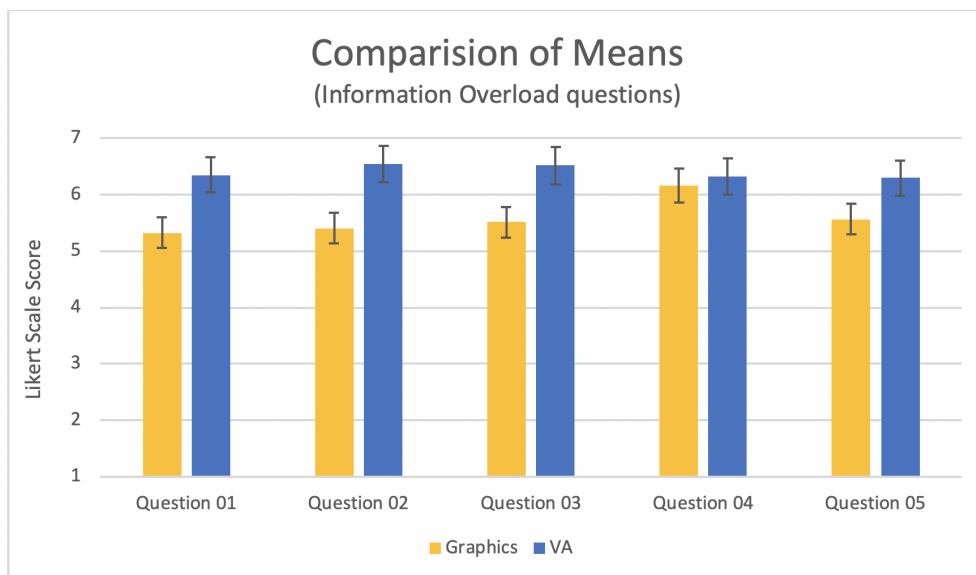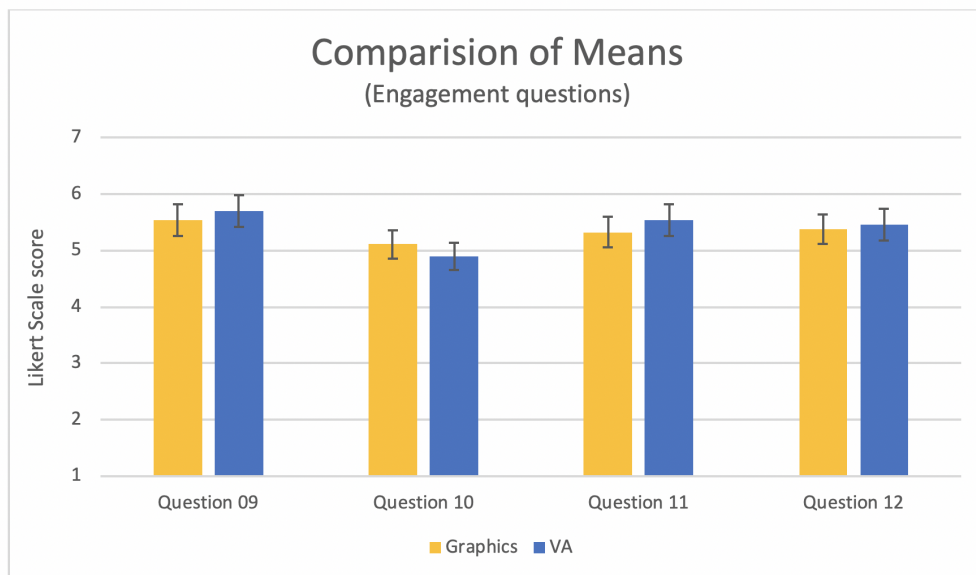

Figure 35: The difference of means of each question regarding Engagement between the Graphics and VA apps (all the scores were converted to total positive scores)

Similar to the Information Overload and Effectiveness, the formula for calculating the total positive score that each participant gave to Engagement was shown below:

The total score of Engagement given by one participant
= (8 - Q9) + Q10 + (8 - Q11) + Q12

Figure 36 displayed the mean of Graphics app was 21,35, and VA app was 21,59 over total points of 28. The difference between these two apps was minimal. Besides, the paired-samples t-test showed that the Engagement Graphics app (M = 21,35, SD = 5,34) and VA app (M = 21,59, SD = 4,99); t (36) = -0,26, p = 0,79 (Table 8). **It disclosed that the difference between these two apps regarding Engagement was not significant.**
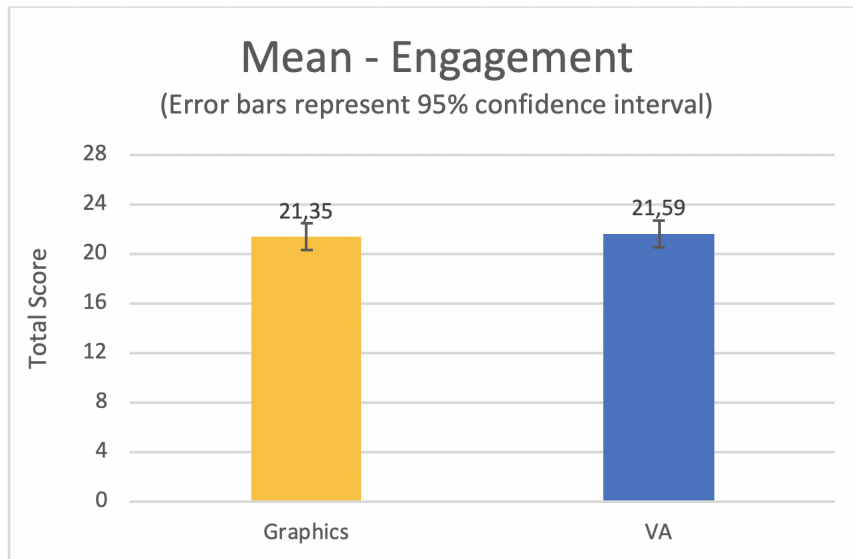
Figure 36: The difference of means of total positive scores regarding Engagement

Descriptive Statistics – Engagement				
	Mean	t	df	p
Graphics - VA apps	-0,24	-0,26	36	0,79

Table 8: Descriptive statistics of the Engagement characteristic

To visualize where the Graphics and VA app stood on the 7-point Likert scale, we divide the total mean score of each app by the total questions of Engagement (4 questions in this case), we get the average score per question:

Graphics: 21,35 / 4 = 5,34

VA: 21,59 / 4 = 5,4

Score different between 2 apps: 5,34 – 5,4 = 0.06

This meant both apps had the nearly same point on the Likert scale of Engagement (Figure 37)
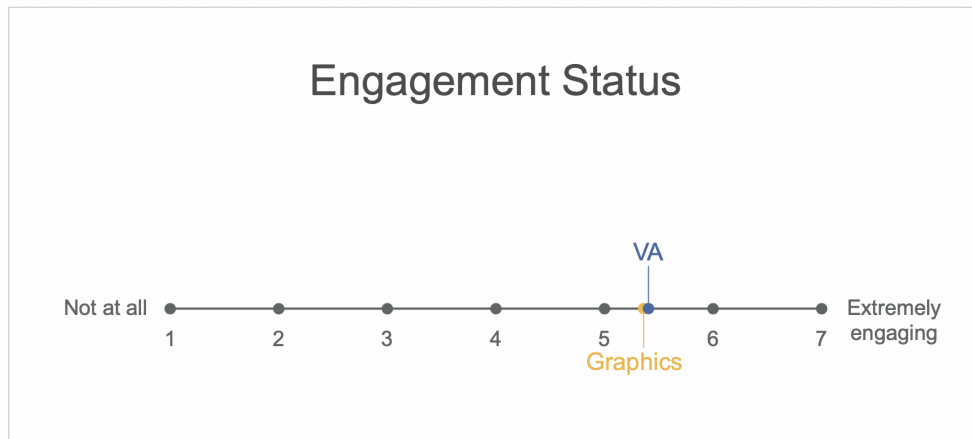
Figure 37: The rank of Graphics and VA apps regarding Engagement on the 7-point Likert scale

5.5   Full-body Virtual Assistant

In the Post – VA app Questionnaire, the last four questions aimed to explore users' thought regarding a full-body VA's appearance in the app. Participants watched a short clip of a virtual staff walking in the supermarket and an image of the AR Google Map showing a fox as the virtual guide (Figure 13 in section 2.2.5); then, they responded to these questions:

- Question 13: I felt to include the virtual staff walking in front of me is UNNECESSARY
- Question 14: I felt the full-body virtual staff helps me to find an item EASIER than following the navigational graphics
- Question 15: I felt the full-body virtual staff BLOCKS my view
- Question 16: I LIKE having the full-body human or animal form as a virtual assistant

Figure 38 showed that users gave low scores to the Full-body VA concept; all the questions received as low as under 4 scores. What made users not interested in the Full-body VA, the qualitative data would answer it in the next chapter, section 6.5.

Figure 38: The mean scores of each Full-body VA's question

5.6 Graphics Versus Virtual Assistant Preferences

The last task of the experiment was the Post – Study Questionnaire. Participants answered six questions regarding Information Overload, Effectiveness, and Engagement to express their preferences between the Graphics and VA apps. Those questions were:

- Question 01: In general, I felt the user interface looks MORE COMPLICATED in the:
- Question 02: I felt MORE INFORMATION OVERLOAD in the:
- Question 03: I was CONFUSED while using the:
- Question 04: I felt it is EASIER TO FIND THE ITEM with the:
- Question 05: In reality, I WILL USE the:
- Question 06: I would RECOMMEND my friends and family the:

To provide the answers, participants circled a number on the 7-point Semantic Differential scales:

	3	2	1	0	1	2	3	
Graphics app								*Virtual Assistant app*

The 7-point scales were displayed as (3 2 1 0 1 2 3) instead of (-3 -2 -1 0 1 2 3) since minus numbers would evoke negative effects that users tended to avoid it (Tullis & Albert 2013). This behavior from users would lead the data to unreliable. Nevertheless, when it came to data analysis, the portion of (3 2 1) from Graphics side was converted to (-3 -2 -1) so that it was able to compute the mean of responses for each question (Figure 39).

Figure 39: The means of each question regarding preferences between Graphics and VA

The above chart showed that though users marked Graphics app as complicated UI and confusing, the number of people chose to use Graphics app in reality was slightly more than the VA app. However, the mean of this was extremely small – 0,14 which was close to 0. This result brought up another question – did not users prefer using any app at all? If it was true, why did they choose to recommend the VA app to friends and family (0,49 as shown in the last bar)? All these queries would be interpreted in the next chapter, section 6.6.

6 Qualitative Results and Discussions

6.1 Overview

The quantitative results in Chapter 5 informed us which prototype performed better in each characteristic – information overload, effectiveness, engagement; also, we recognised users' preferences regarding Graphics/Virtual Assistant app, and the full-body Virtual Assistant. In this chapter, we discover what were the reasons behind those choices by going through users' comments.

During the experiment process, I encouraged participants to elaborate their answers by providing opinions in the questionnaires. Those who gave fewer remarks, I tended to ask them more questions at the end of the test, such as "Can you share with me about your thoughts regarding the two prototypes? Which one do you think better? What do you like and dislike? Why do you think that way?", etc. This activity helped me to collect comprehensive information from written comments and notes from the verbal discussion. Nevertheless, it also caused a challenge in analysing the wording responses. Tullis & Albert (2013) suggested summarising users' opinion by copying all the verbatim comments into a software for creating word clouds, such as Wordle.net. This tool displayed the words which were repeated many times in the bigger sizes; hence, it drew attention and informed researchers what the keywords that users mentioned most were.

Before applying the word clouds method, I created three tables: Feedback of Graphics app (Appendix A.10), Feedback of VA app (Appendix A.11), and Feedback of Preferences between Graphics vs. VA (Appendix A.12). Each table contained questions of the respective questionnaire and comments from participants. Participants' answered were divided into two columns - Negative/Neutral feedback and Positive feedback. Organizing information in this way helped me to clarify what users like and dislike, what was fruitful and what needed to be improved. For instance, the Question 16 (section 5.5) "I LIKE having the full-body human or animal form as a virtual assistant", the dominant words from participants' comments were animal, fun, fox, etc. (Figure 40). Those words were summarised from all comments, and word clouds revealed the terms which users frequently referred to.

Figure 40: Word cloud of responses to one of the questions regarding full-body human or animal for VA

In the next sections, I reflect the qualitative results on these aspects - Information Overload, Effectiveness, Engagement, Full-body Virtual Assistant, Graphics Versus Virtual Assistant Preferences, as well as the three hypotheses.

6.2 Information Overload

Hypothesis 1: Virtual Assistant simplifies the Augmented Reality user interfaces (reduces information overload).

This hypothesis was supported according to the quantitative data result.

The first screen of the Graphics app consisted of many category labels and a search button. When being asked "What will you do to find Maarud Peanut?", 100% of participants tapped on the "Snacks" label. This action led them to the general snacks section but not to the specific product's location. After users had done their task with this prototype, I showed them the first screen again, and then they realized there was the search button. "I did not notice the product search function at first as the product categories took up a lot of attention", many people had given similar comments like this.

In the other hand, the first screen of the VA app asked users "What are you looking for?", and provided the search function with both voice and text options. It reduced all extra information so that users only had to focus on one point – to input what they are looking for. "It took me longer to understand the Graphics app because I had to make sense of the information/categories first. The VA was asking me directly what I searched for and I just answered without even looking much at the screen", a user noted. By showing the straightforward option, the VA app saved users on time, getting lost, and confused. Therefore, the VA app was significantly less informa-

tion overload in comparison with the Graphics app.

However, users still gave neutral and positive comments for the Graphics app: "A nice balance of information, though I think that the first screen can be a bit overwhelming for some", "The labels on top distracted me from realising there was a search bar on the bottom of the screen. However, I do not think the buttons themselves were confusing, they just did not provide the accuracy I required for the task", etc. These comments explained why though participants felt there were many things displayed on the Graphics app's UI, both Graphics and VA apps gained high points on the mean scores of information overload status (as shown in section 5.2).

6.3   Effectiveness

Hypothesis 2: Virtual Assistant in an Augmented Reality app helps users to achieve their goals more effectively than a standard Augmented Reality app which contains only graphic elements.
   This hypothesis was supported according to the quantitative data result.

As 100% of participants clicked on the "Snack" button, the Graphics app brought users to the snacks area only instead of the specific location of the product that the task required. This meant none of them could find Maarud Peanut. I asked participants what they would do in reality when they were at the right area but could not find the desired items. Most of them replied that they would walk back and forth to find it - "I rarely ask for stuff in stores, I prefer looking until I can find it, within reasonable time", a user commented. In this case, because the proper feature to perform this task were not selected, users were unsuccessful in locating the product straightaway. In the situation of walking around in the physical store but still unable to find the desired item (like I could not find the sauce and came up with this design concept), users would think that the app was useless and might get rid of it. While with the VA app, after users inputted the searching terms, it led them to the exact location effortlessly. If participants recognised the search button and used it, the Graphics app would bring them to the exact product's location as the VA app did. Obviously, participants were unable to complete the task with the Graphics app due to the information overload on the first screen. Here, we found the correlation: the information complexity diminished effectiveness of the app. In other words, the simpler user interface of the VA app kept users away from confusion and helped them to perform the task efficiently. The VA app, therefore, gained higher points and was significantly more effective than the Graphics app.

Some people had noted to the Graphics app: "I didn't notice the search bar at once because the categories are in my focus. Anyway, it is easy to interact with the app when you know about the features", "The first screen was not easy to understand but the animations happened on the floor was", "The arrows on the floor made it easy to find the way", etc. These judgements were the reason why participants did not successfully complete their task with the Graphics app; still, both Graphics and VA apps gained high points on the mean scores of effectiveness status (section 5.3). The navigational arrows in the Graphics app and the blue lines in the VA app, in fact, effectively guided people to the selected location (Figure 41 and Figure 42).

Figure 41: Navigational arrows in the Graphics app. (Click here for the video)

Figure 42: Blue guidelines and the indicator in the VA app. (Click here for the video)

6.4 Engagement

Hypothesis 3: Virtual Assistant will enhance the engagement between users and an Augmented Reality app.

   This hypothesis was not supported according to the quantitative data result.

However, it did not mean that the VA app was not engaging, or users disliked the VA version. The result in section 5.4 showed that the VA app had 21,59 points which were slightly higher than the Graphics (21,35 points) over total points of 28. The difference between them was not significant. The question was why VA gained superior in the two characteristics - less information overload and more effective, but it was not more engaging than the Graphics app. There were a few reasons behind this.

Firstly, also the biggest obstacle prevented users from immersing in the VA, was that talking with a VA in public places caused uncomfortably. Many people had similar opinions: "I felt it is fun to use, but I would not use the virtual assistant in public because it will be too much noise", "I don't like assistant talking to me in public places, I would prefer getting the info with text only, and type to input info. I could possibly listen if I was using some Bluetooth headphones", "I don't like to voice out to everyone at the store what I am buying", etc. This reaction was corresponding to the survey done by Dunn (2017). Dunn found out that people who used virtual assistant such as Siri or Alexa tended to use it at home (39%) or in the car (51%), those places where they had comfort with privacy. Only 6% said they use VA in public (Figure 43).
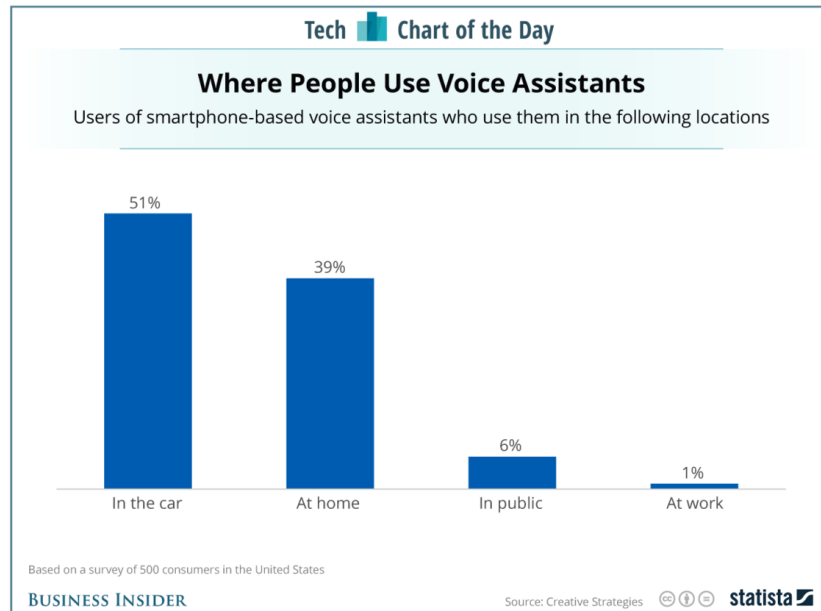
Figure 43: Places where people use voice assistants. Source: (Dunn 2017)

Actually, this issue was considered before I developed the prototypes. That was the reason why the text-input option was designed next to the speech input which allowed users to talk or to write. In addition, the app provided both voice and text output. For instance, when the VA said "Gilde sausage is over there. Please follow me", the app included both sound and message text box (Figure 44). However, I did not consider having the "Mute" option. As a result, users thought that they always had the app with voice, thus, not likely to use the VA app in reality. This reason caused the VA app losing engaging points.

Figure 44: The VA app provided both voice and text output but has no "Mute" option

Secondly, users thought that although they were confused with the Graphics app's first screen, this version gave more options as it provided not only a search button but also virtual labels. These features allowed them to find a specific product, and at the same time, let them indicate different categories' location in the supermarket. One of the participants commented that "I would need to ask the virtual assistant every time I look for a product, while on the first screen of the Graphics app, I roughly had in mind where the location of vegetables, fruits, or meat are." This opinion caused by the misinterpretation. Since in my plan, the VA would work as an artificial intelligent assistant that users could ask for anything, such as a product name, the area of a category, promotions, etc. but I did not clarify at first, and made participant thought that the VA could only locate a single item. Consequently, the VA app had lost points on the engagement aspect.

The third reason came from the opposite opinions of two groups of participants. The first group (included 2 – 3 people) mentioned that they would not need an AR app for shopping. I called

this group as group A. In group A, there were group A1 and A2. Group A1 said that they might not use this type of app because they visited their local supermarkets frequently; hence, they knew where the products were placed. (Anyway, they forgot that I had given them the scenario of being in a big and new supermarket for the first time. And even customers visited their local supermarkets often, for sure, sometimes they would need to buy some products that they did not always buy; thus, they might be not sure where the items were). The other one, group A2 were those who commented "I like to go through all the rows and find new products and items I haven't thought about" - this group prefer exploring rather than getting the products quickly. The second group, I named it as group B (majority number of users), stated that they liked both apps as both were attractive, practical, and fashionable technology. Certainly, though group A and B had contrasting ideas, they would give equal responses to the apps – either both apps gained low points or high points for the engaging characteristic. It also meant that there was no significant difference in engagement between the Graphics and VA apps.

These three reasons explained why the VA app prevailed over the Graphics app on information overload and effectiveness but not on the engagement aspect.

6.5   Full-body Virtual Assistant

The full-body VA concept received low scores in general (section 5.5). Most of the participants thought that the full-body VA was unnecessary; to them, navigational arrows and lines were good enough for showing the way. Some of them remarked on the full-body feature as "It's a cool feature, but I felt that the pop-up "head" with arrow indicators was enough", "I prefer the blue lines to the assistant walking in front of me. For some reason, I feel that it is more clear and easier to follow", "It kinda feels like I'm a young child being dragged around by my mother". Users also felt that the virtual staff blocked their view: "I do think it can get in the way, and I would be a little afraid of crashing into someone or something. I also feel it would require me to look at the screen more (maybe constantly), whereas the navigational graphics, I would just need to look down a few times (because I can remember which way the line is going for a short amount of time)". It was understandable when users afraid of this problem since the virtual staff appeared as a full opaque form in the clip (Table 3, Step 15, section 3.3.4). If its opacity were reduced like the virtual polar bear gym trainer in Figure 18 (section 4.1.1), users' reaction might be different. "It could be better to have the virtual staff semi-transparent", a user noted.

Though participants preferred navigational line, many of them believed that the full-body VA was helpful for the elderly "It doesn't matter if I have a physical body to guide me through the store, but for an elderly person this would be a great option". These remarks were correlative with the Literature Review (section 2.2.4) which mentioned some projects successfully employed VA to help the elderly and cognitively impaired people. Perhaps, further work should be implemented to amplify the role of the full-body VA.

While the majority found distasteful in full-body human, more participants showed interest in the animal form. In the last question of the Post – VA app questionnaire, I showed users the image

of the little fox from AR Google Map (Figure 13 in section 2.2.5), and asked if they preferred the full-body human or animal form as a virtual assistant. All leaned to the animal version: "The fox is much better than the lady", "At first, I feel the women walking in front of me is not necessary, it will block my view. But this image, with this little cute fox, I start thinking that maybe having a small and cute animal will help? Users can choose different kind of character based on their mood, and it will have a stronger memory link with the unfamiliar place." Still, some participants noted that "human/animal display is not needed for way showing/navigation", "It would be really fun, but I think it is too much for a navigation app. Precise information is more helpful". These comments explained why the full-body VA concept gained the low score in general (section 5.5).

6.6   Graphics Versus Virtual Assistant Preferences

In section 5.6, the results showed that despite users evaluated the Graphics app having more complicated and confusing UI than the VA app, slightly more people tended to use the Graphics app in reality. But its mean score on the grading scale (-3 -2 -1 0 1 2 3) was very small – 0,14 which was almost "0". It did not mean that users did not like any app at all; in fact, both apps were received equal favour.

How do we recognise the Graphics and VA app were equally attracted? During the experiment, I experienced the "Wow" effect from participants when they interacted with the prototypes. No matter participants had the VA or Graphics app first, some expressions I heard were: "I think that's cool, wow!", "ha ha nice!", "Is it the real product?". Some people even said "Thank you!" to the VA after she said "Enjoy shopping!". Or a friend of mine met me at a supermarket and asked: "Can we use your apps?". It was a joke, anyway, it showed that many users were impressed with the apps, and they remembered how it worked, in what context. The users' enjoyment reflected the engagement of the product because it was fun, useful, trustable, or surprising; Obrien & Toms (2008) mentioned these elements and listed some attributes which contributed to the engagement, such as aesthetics, affective and sensory appeal, motivation, etc. (Figure 45)

Attributes from the theories	Theories				Attribute of engagement?
	Flow theory	Aesthetic theory	Play theory	Information interaction	
Aesthetics		✔	✔		Yes
Affective appeal		✔	✔	✔	Yes
Attention	✔	✔			Maybe
Challenge	✔	✔	✔	✔	Yes
Feedback	✔		✔	✔	Yes
Goal-directed	✔		✔		Maybe
Meaningfulness	✔	✔			Maybe
Motivation	✔	✔	✔		Yes
Perceived control	✔			✔	Maybe
Sensory appeal		✔	✔		Yes

Figure 45: The attributes which proposed relevancy to engagement (Obrien & Toms 2008)

Both Graphics and VA apps produced equivalently enjoyable emotion for users during the study. When answering question 05 in the Post – Study Questionnaire (Figure 46), some users asked me "If I like both, what number should I choose", I recommended them to selected "0".

5. In reality, I WILL USE the:

	3	2	1	0	1	2	3	
Graphics app								*Virtual assistant app*
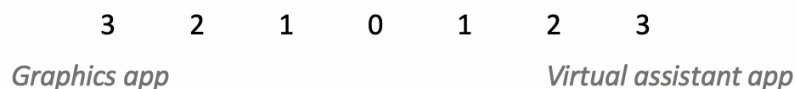
Figure 46: The question which many users circled "0" as they liked using both apps

To explain why the mean score was not above "0", in other words, why it did not lean to the VA app (even as small score as 0,14) instead of the Graphics app, the answer was found in the Engagement section 6.4 – users felt not fascinated to talk to the VA in public places. Another reason for this result was also discussed in the second point of section 6.4 – misinterpretation of the VA's function. Participants felt that "to find a specific item seemed more convenient with the VA prototype; however, if the task was to find multi-products, the Graphics prototype could be more useful". Similarly, another one commented "The Graphics app may be a bit more complicated, but it seems more functional. Very clear what you can do, either you want a more general guide

or to find a specific product". Therefore, this group of participants concluded: "Graphis app is more practical".

Nevertheless, when being asked "which app would you recommend your friends and family", more people selected the VA app. The responses' mean score of this question was 0,49 towards the VA app (Figure 39 in section 5.6). Users who chose to recommend the VA app noted that "I like the assistant when she asked "what are you looking for", this will make it easier for elderly people or kids, who are not familiar with new technology, to use the app", "Based on the simple interface and less input option, VA is better for family when they already have predefined items to buy", "My parents do not speak much Norwegian, so talking to a staff is difficult for them. It would be easy for them by just following a line on the floor to find the product", etc. These opinions were the reason why the VA app was received more recommendations from the users.

Anyway, why was it only 0,49 but not a higher score? Because other participants thought that they would recommend different apps for different users. For instance, young adults who were not in a rush and like exploring could use the Graphics app; while the VA app might be suitable for people who were interested in playing with new technology, or the elderly who prefer straightforward function and less interaction with the devices. "I'd recommend both since they fit different personalities", a user commented.

6.7   Limitations

In this section, I discuss some limitations regarding the prototype development and the experiment.

- As this study aimed to explore users' behaviour towards new technology - AR and VA, there were many hindrances during the development process. Though AR was not a very new concept, its application to mobile devices contained limitations as mentioned in Chapter 02, section 2.1.2; hence, to create smooth AR experience prototypes were highly challenging. At first, I planned to build up a physical mockup of a supermarket (Figure 20, section 4.1.2) so that participants could walk around to find the required items with an AR app in the mobile device. However, as discussed, it was unable to execute.
- To achieve another kind of high-fidelity prototype, Adobe After Effect was selected as the main instrument. But this approach also contained some disadvantages. For instance, users had to sit in front of the screen instead of walking around with the phone as it was supposed to be. This situation somehow reduced the AR experience; consequently, actual reactions/feedback might be missed.
- Another obstacle from the technology part was the 3D character animation. Though I had my friend helped to transfer the full-body VA to the video; still, it was not exactly as what I was looking for. In addition, the clip was too short, it ended before users gained some experience with the full-body virtual staff. This issue could add up to the reason why users were not attracted to the full-body VA.
- Lastly, the limitation came from the non-diversity of participants. Most of the users were

NTNU students aged from 20 – 30 years old (Figure 47). Different demographic profiles would reveal distinct facts. If I could get more users from the age group of 31 – 55 or even above that, with mixed of single people and people with kids, I might get more interesting qualitative data. Certainly, a person who shopped in a supermarket alone and a person with children would have different behaviours. One might enjoy wandering around while the other one would like to get the shopping done quickly; hence, their attitudes of using the app probably would be different. Whitenton (2019) advised to apply user categories when we design mass-market products as it would improve the UX outcomes. For instance, designers could estimate cutoff points which divide clusters of users by the percentage of people who visit daily, weekly, etc. This aspect should be considered in future research.
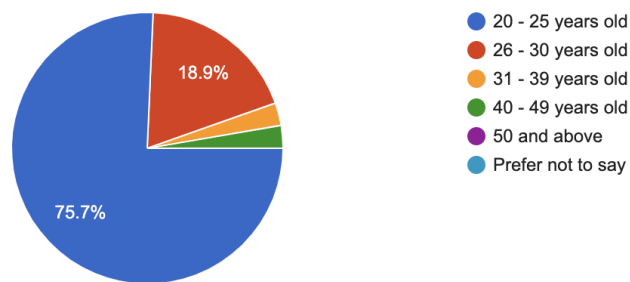
Figure 47: 95% percent of participants were in the age of 20 – 30 years old

6.8   What should be done better

The UI of prototypes could be designed in various styles, and different designs caused different ways of interaction. Though I had considered carefully and referred to several design guidelines (section 4.2.1), it was impossible to produce perfect apps in the first round. As always, good designs involved in the iterative design process, which "allows one to shape the product through the process of design, test, redesign, and retest activities" (Rubin & Chisnell 2008, p.14). Thanks to the experiment, I could not only test my hypotheses but also recognised some issues from the prototype designs. In the below part, I listed some points which could be done better in the Graphics app, VA app, and the experiment.

6.8.1   For the Graphics app

- Though its first screen provided both functions – to find a general category or a specific product, 100% of participants did not realize the search button to successfully complete their task. "Maybe the search option should be more elevated if the goal is to find specific products that customers often ask for", one of the users' comment worth considered. Or "maybe make a button to choose categories next to the search button", another suggestion

from the other user. This idea was interesting as if all the category labels (e.g., Seafood, Dairy, Fruits, etc.) were combined in one button, it could save screen space and reduced information overload. Of course, usability testing should be conducted after a redesign to evaluate if the new solution worked.

- "The flashing of the name of the product makes me not sure if it was flashing directly over the product, next to it, below it, or above it", noted a user. On the last scene of the Graphics app, a banner was displayed to indicate the product's position (Figure 48); however, it did not include an arrow to point where the product exactly was. Users were confused due to this unclarified sign. A pointer or an arrow as a visual clue would be helpful for this vagueness.

Figure 48: The product's banner on the last scene had not indicator which made user confused where the exact product's position was.

6.8.2 For the Virtual Assistant app

- A user remarked that the VA's voice was slightly creepy/unnerving. The voice over was produced by Animaker.com which allowed users to input texts and turned it to voice. Though it provided options to adjust the speed and pitch, the tone of voice still sounded artificial. This issue reduced the human feeling of the VA which I aimed to achieve. Perhaps instead of using this software, I should look for a native English speaker and record her voice. It would sound much more natural and gave users the feeling of talking to a human being. Milne's research (Milne et al. 2010), Development of a Virtual Agent Based Social Tutor for Children with Autism Spectrum Disorders, has this similar problem. She mentioned in her findings that the tutors' tones of voice were not always accurate; the intonation must be as

realistic as possible because it reflected the speaker's emotions and intent.

- The "Mute" option should be included (as mentioned in section 6.4) so that users would feel comfortable to use the VA version in public places.
- Opacity of the full-body VA in the clip should be reduced so that it did not block the in front objects, and the clip need to be extended long enough for users to fully acknowledged how the virtual staff worked.

6.8.3   For the Experiment

- The Post - Study Questionnaire (to explore the Graphics vs. VA preferences) was handed out to participants after the Post - VA app Questionnaire. This meant users had answered the questions 13 - 16 (section 5.5) regarding the full-body VA. Therefore, when comparing the Graphics and VA apps, some people might judge between the Graphic and full-body VA apps but not the Graphics and original VA apps (with face only). This could affect the Post - Study result. I only realized it when one of the users asked me "Am I supposed to compare the Graphics with the full-body VA?", "No, the VA with face only", I replied. Thereafter, I noticed all the following participants about this, but I was not sure if the previous users understood it correctly.

To summarise, the VA app was significantly less information overload and more effective than the Graphics app, but on the engagement aspect, the two apps were not significantly different. According to Leedy & Ormrod (2015), the study's results would be more convincing when both qualitative and quantitative data led to the same conclusions. In this study, the qualitative data corresponded to the quantitative results, and it explained the reasons behind participants' choices. In the next chapter, I reflect on the contributions of this master thesis, the learning outcomes, and future development and research.

7 Conclusions

This research study has brought me through different phases of experiences. It is a mix of exploration, challenge, acknowledgement, excitement, and sometimes standstill. Nevertheless, it is like a delicious dish which consists of various flavours – a bit sour, a bit sweet, and a little spicy. A chef will never be a master chef if he uses the same recipe for every course. A designer will never be a creative problem solver if he keeps using the same tool and mindset for every project. I am happy that I have tried different approaches to create the two augmented reality (AR) apps – Graphics and Virtual Assistant (VA). These two prototypes not only promoted the advantages of new technology but also demonstrated how AR and VA could be applied to solve problems in everyday life. In this chapter, I discuss the three aspects - (1) what are the contributions of this research, (2) what I have learnt throughout the project, and (3) what the future work are to bring these AR apps to the next level.

7.1 Contributions

Generally, this research contributes three values to the design industry:

- It is an experiment of combining the two technologies – AR and VA. As mentioned, it is minimal research on the compound of these two elements. This study, therefore, produces a general background and findings for the future relevant research.
- It is a state-of-the-art of Wayfinding. We have been through the history of Wayfinding from physical maps on the early days to digital 2D maps, and now is the era of immersive Wayfinding that employs AR. There are many apps in the process of testing or currently available on Google Play/Apple App Store that employ AR to help people finding objects. For instance, AR Google Map (Liptak 2019), AR Car Finder (AugmentedWorks 2010). In addition, more companies chose to invest in the AR solution in Wayfinding, such as 22MILES. This tendency proves the high potential of AR Wayfinding. My project strengthens this trend, and we will soon have more practical AR apps for not only outdoors but also indoors such as supermarkets, shopping malls, airports, hospitals, museums, etc.
- Designers are creative problem solvers. In this study, I employ technology to solve the problem that could happen to everyone. According to the survey regarding Issues of shopping in supermarkets (Figure 19), "unable to find desired items" is the major problem. Some participants responded that they would either leave the store or "find an alternative item or just skip it". This issue, in fact, not only frustrates customers but also affects the sale of supermarkets and the brands carrying those concealed items. Therefore, I believe my AR app not only provides users a tool to shop with ease but also helps supermarkets to offer a better service.

Coincidentally, my project is on the same line with what CoopX is targeting. CoopX is the new department of Coop; its mission is to develop digital products and services to solve everyday problems in the grocery and building sectors (Redaksjonen 2019). When I saw the job ad from CoopX (Figure 49), I sent them my project and was invited to Oslo to present the two prototypes. The representatives from CoopX were interested in my AR apps as it creates the "future shopping experience" which CoopX aims to achieve.

Figure 49: CoopX's job ad mentions its target is to produce digital products and services that provide people the "future shopping experience"

A design is successful when it is serviceable or resolves a problem. Though there is still a long way to accomplish these AR apps, I am happy that the design concept and prototypes have been met with strong industrial and commercial interest.

7.2   Learning Outcomes

One of the senior UX designers has told me that the exciting part of interaction design is that we will learn new thing from every new project, thus, we will never get bored while working in this industry. It is completely true. Thanks to this project, I gain different skills and knowledge.

- I have learnt to use new design software such as After Effect which helps to produce high-fidelity prototypes.
- I have the chance to explore new technology, the in-depth concepts of AR and VA, from both theory and practice. Literature Review provided me the comprehensive understanding while the experiment gave me the overall picture of its strength and weakness in practice. Knowing how new technology work helps me to implement them in a proper way.
- I have learnt variety of user experience (UX) metrics to be applied for different usability scenarios such as Performance metrics, Issue-Based metrics, Self-Reported metrics, Behavioral and Physiological Metrics, Combined and Comparative metrics. Though I did not apply all of them to this study, the knowledge of these UX metrics will be helpful for my future projects. Besides, through the research process, I learnt the techniques of collecting different types of data, analyzing them in various angles, and professionally presenting data to stakeholders. These are powerful skills that all Interaction Designers need to be equipped. I believe I will use them repeatedly in my working life.
- If we compare an interactive product with human anatomy, the UI design is like human skin which exposes its look; program code is the spine/ bone structure which constructs the shape and executes an action, UX design is the nervous system which produces emotions in response to every event. Emotion or "sensation", as Harari (2017) mentioned in Homo Deus, is the centre element of human body. It decides the consequent action after the sensation has been produced. For instance, if a person felt that the AR app is fun and helpful, he will use it again; on the contrary, if his interaction with the app causes boring or annoying experience, he would not keep that app in his device. This reaction shows how important to understand users' thoughts and feeling. By saying this, I mean when conducting usability testing, besides figuring out what works and what does not, we should always look into the reasons behind it - "why". Why users do not like it, how they feel, what their thoughts are, etc. Therefore, in my opinion, qualitative research needs to be included in every usability testing.

In conclusion, there are two important points I have learnt in this project - (1) to conduct a proper user study; and (2) UX research is significantly crucial in interaction design, though it cannot be seen like UI, it decides the success or failure of a project (e.g., the failed AR engine assembly app developed by the Audi team that mentioned in Chapter 1).

7.3 Future Development and Research

"We are still learning a lot; this is still very early", stated Marek Gorecki (an engineering manager for Google Maps) regarding the new AR feature in Google Map (Metz 2019). The AR and VA concepts are promising; it requires a lot of research and usability testing to amplify their effects. Also, for my prototypes, many things could be done to improve and turn them to the fruitful apps. By listing several points below, I hope they are not only for me to explore further, but also for those who are interested in AR and VA found inspired topics for their research.

- Results from the experiment showed that both prototypes are equally engaging. Based on the context of use, users will select the Graphics or VA app. Possibly, we combine these two apps to make use of each one's strength; at the same time, we give people flexibility in selecting the favourite version in one app.
- The app could provide various appearances of VA in terms of face looks and full-body types. As discussed in section 6.5, the full-body virtual staff is perhaps suitable for the elderly, but teenagers and children may be more interested in the animal form. Choosing the full-body VA could be as fun as choosing an avatar. This feature would make the app more fun to use. "I feel like it is gamification of something routine", said a participant when he shared his thought regarding the full-body VA.
- To serve not only people in Norway, the app may also reach further markets by including different languages. In reality, "cannot find items in supermarkets" is common; it happens to anyone from anywhere. People, therefore, will need this kind of app for the stress-free shopping experience.
- Besides the significant problem of "cannot find items", there are some other issues that people encounter while shopping in supermarkets, such as "could not find the price of items", "hard to identify which brand offers the lower price", etc. (Figure 19, section 4.1.1). It would be beneficial if the app can provide more features to solve those difficulties.
- Instead of inputting a single item for searching its location, I will extend its function so that users can input the whole shopping lists. By this way, it saves time on keying in one by one product, and the app also produces the shortest path to collect all of those items in one round. This shortcut could be a great solution for shoppers who have limited time for shopping. The "shopping list" idea was also suggested by the CoopX representatives when I presented this project to them.
- The advantages of artificial intelligence (AI) could be utilized. For instance, suggested words/items appear when people are using the search function; if users have found the Gilde sausages, the app recommends the best sauce for it; or, the AI learns users' behaviour/shopping habits and provides "proposed need-to-buy items", then users will tap to confirm or wipe out to cancel, etc. The suggestion function will not only create a better user experience but also increase sales for the supermarkets.
- To include different user groups in the study as recommended in section 6.7. When the design is aimed for large audiences, Whitenton (2019) suggests applying "frequency of use". Variances in frequency of use is both cause and effect of the significant differences between types of users: (1) Frequent use *causes* acquaintance with the user interface and

quick actions on repeated tasks, (2) Frequent use is *an effect of* needs and goals: people use it often as the contents or tasks are important to them (Whitenton 2019). Understanding this concept helps designers to oversee their user segments properly.

All the above suggestions not only aim to achieve a wholly functional app but also to attract more people from different demographic backgrounds, such as participants in group A1 and A2 mentioned in section 6.4. Every proposed concept, certainly, need to be examined to evaluate if it is practical or overwhelming. In exploring an area, research is rarely conclusive (Leedy & Ormrod 2015). Additional problems or questions appear; thus, we are required to begin a new process. In other words, "research begets more research".

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A   Appendices

A.1 Protocol

Protocol

1. Materials

- A laptop (to play the prototypes)
- Mobile phone (as remote control)
- Note
- Printed consent forms
- Fruits, drinks, snack and chocolates (as compensation)

2. Script:

- Welcome participant: "Hi (name), thank you for participating in my project. For the quick introduction, I am having an experiment to compare the two prototypes. Here is the consent form which informs you more about the project, as well as your rights as a participant".
  Hand over consent form. While waiting, note on the Experiment table.
- "Now, I'll summarise what you are going to in this experiment: imagine you are in a new supermarket for the 1st time, you need to buy some products but you don't know where they are, there is nobody for you to ask. So, you use the AR mobile app to find those items.
  In this experiment, you will interact with 2 prototypes of AR mobile app. The difference between them is that one employs virtual assistant and the other one uses graphics elements. There are 3 questionnaires in total - one after each prototype and the 3rd one is to compare those 2 mobile apps. So please answer all the questions from your point of view"
- "So, are you ready?" :)
- Firstly, please fill in this Demographic Survey
- "For the 1st prototypes, your task is to find this product: Maarud peanut/ Gilde sausage"
  Show product image
- After finish the 1st prototype *(floor plan)*
  Post - app Q (If VA app, note on the last questions of showing clip)
- Before 2nd prototype
  Show product image
- After finish the 2nd prototype *(floor plan)*
  Post - app Q (If VA app, note on the last questions of showing clip)
- Post - study Q
- "Do you have any other thoughts or comments would like to share with me?"
- "Thank you so much for your time", please take anything that you like: fruit, chocolate, snacks, etc.

A.2   Consent Form

Are you interested in taking part in the research project

TANGIBLE VIRTUAL ASSISTANT?

This is an inquiry about participation in a research project where the main purpose is to find information about users' thought and opinions regarding Augmented Reality (AR) and Virtual Assistant (VA). In this letter I will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
If you decide to participate, you will be asked to interact with two prototypes, to fill in 1 survey and 3 questionnaires. The test is a part of my Master Thesis and it should take around 20 - 25 minutes.

This experiment aims to compare the two augmented reality (AR) prototypes. The difference between them is that one employs virtual assistant and the other one does not.
The purpose is to find out which prototype:
- Simplifies the user interface (UI) better
- Helps users to achieve their task more effectively
- Enhances the engagement between users and the mobile app

Who is responsible for the research project?
I myself, Lam Kim Khoi and NTNU i Gjøvik is the institution responsible for the project.

Why are you being asked to participate?
To gain the validity and reliability of this study, I hope to have at least 30 people to join the experiment. Participants are selected randomly, mostly young people who like trying new technologies.

What does participation involve for you?
In this experiment, participants will interact with 2 prototypes of AR mobile app. The difference between them is that one employs virtual assistant and the other one uses graphics elements. There are 1 demographic survey, and 3 questionnaires in total - one questionnaire to be answered after each prototype and the last one is to compare those 2 mobile apps.

- The demographic survey includes age groups, gender, and basic information such as "Do you have any idea of Augmented Reality and Virtual Assistant?". Your answers will be recorded by Google Form.
- Post-app (Graphics and VA) questionnaires contain similar questions which asking people for their opinions regarding information overload, effectiveness, and engagement in each app. Your answers will be recorded by Google Form.
- Post-study questionnaire aims to compare the two apps. Also, it focuses on the three research questions - information overload, effectiveness, and engagement. Your answers will be recorded on paper.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how I will store and use your personal data

I will only use your personal data for the purpose(s) specified in this information letter. I will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- My supervisor may help me on analyzing the data but he will not know the responses come from who as everything is saved anonymous.
- I will replace your name with a code. The list of names and respective codes will be stored separately from the rest of the collected data.

All your information such as name, age, gender, etc. will not be recognizable in publications

What will happen to your personal data at the end of the research project?

The project is scheduled to end by end of June 2019. All data will be deleted including the digital and paper versions.

Your rights

So long as you can be identified in the collected data, you have the right to:
- Access the personal data that is being processed about you
- Request that your personal data is deleted
- Request that incorrect personal data about you is corrected/rectified
- Receive a copy of your personal data (data portability), and
- Send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

I will process your personal data based on your consent.

Based on an agreement with NTNU i Gjøvik, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:
- NTNU i Gjøvik via:
  - Mariusz Nowostawski (Professor/ main Supervisor): email address, (phone number)
  - Lam Kim Khoi (the researcher): email address, (phone number)
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Researcher

Consent form

I have received and understood information about the project Tangible Virtual Assistant and have been given the opportunity to ask questions. I give consent:

☐ to participate in the experiment (interact with prototypes and answer questionnaires)

I give consent for my personal data to be processed until the end date of the project, approx. end of June 2019

(Signed by participant, date)

A.3   Demographic Survey

Demographic Survey

This user study is part of Lam Kim Khoi's Master Thesis work

* Required

1. **Your age group** *
   Mark only one oval.

   ( ) 20 - 25 years old

   ( ) 26 - 30 years old

   ( ) 31 - 39 years old

   ( ) 40 - 49 years old

   ( ) 50 and above

   ( ) Prefer not to say

2. **Your gender** *
   Mark only one oval.

   ( ) Female

   ( ) Male

3. **Have you used or know about Augmented Reality app?** *
   Mark only one oval.

   ( ) Yes

   ( ) No

4. **Have you used or talked to any virtual assistant (e.g., Siri, Google Assistant) before?** *
   Mark only one oval.

   ( ) Yes

   ( ) No

5. **Will you talk to a virtual assistant in public areas (such as supermarket)?** *
   Mark only one oval.

   ( ) Yes

   ( ) Not with voice, I prefer typing

   ( ) No, I do not like using virtual assistant

   ( ) Other: _____

6. **Others (please specify)**

   _____

Thank you! :)

A.4   Post - Graphics App Questionnaire

Post - Graphics App

This user study is part of Lam Kim Khoi's Master Thesis work

1. **I feel that there is TOO MUCH information to manage in this app** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

2. **Comments:**

   _____

3. **It was EASY to input the item that I was looking for** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

4. **Comments**

   _____

5. **The user interface is CONFUSING** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

6. **Comments:**

   _____

7. **The information on the screen is EASY to understand** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

8. **Comments:**

   _____

9. **The organization of information in this app was NOT clear** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

10. **Comments:**

    _____

11. **I COULD find the exact location of a specific product using this app** *
    Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

12. **Comments:**

    _____

13. **I felt that it was NOT easy to complete the task with this app** *
    Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

14. **Comments:**

    _____

15. **I was able to find the item using this app with LITTLE effort** *
    Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

16. **Comments:**

    _____

17. **I felt this app is NOT fun to use** *
    Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

18. **Comments:**

    _____

19. **I WILL use this app in the reality** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

20. **Comments:**

_____

21. **I do NOT like the interaction way of this app** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

22. **Comments:**

_____

23. **I WOULD recommend this app to my friends and family** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

24. **Comments:**

_____

Thank you! :)

Powered by

Google Forms

A.5   Post - Virtual Assistant App Questionnaire

Post - Virtual Assistant App

This user study is part of Lam Kim Khoi's Master Thesis work

* Required

1. **I feel that there is TOO MUCH information to manage in this app** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

2. **Comments:**

   _____

3. **It was EASY to input the item that I was looking for** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

4. **Comments**

   _____

5. **The user interface is CONFUSING** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

6. **Comments:**

   _____

7. **The information on the screen is EASY to understand** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

8. **Comments:**

   _____

9. **The organization of information in this app was NOT clear** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

10. **Comments:**

_____

11. **I COULD find the exact location of a specific product using this app** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

12. **Comments:**

_____

13. **I felt that it was NOT easy to complete the task with this app** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

14. **Comments:**

_____

15. **I was able to find the item using this app with LITTLE effort** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

16. **Comments:**

_____

17. **I felt this app is NOT fun to use** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

18. **Comments:**

_____

19. **I WILL use this app in the reality** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

20. **Comments:**

_____

21. **I do NOT like the interaction way of this app** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

22. **Comments:**

_____

23. **I WOULD recommend this app to my friends and family** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

24. **Comments:**

_____

Before you answer the next questions, please call the researcher for showing a short clip

25. **I felt to include the virtual staff walking in front of me is UNNECESSARY** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

26. **Comments:**

_____

27. **I felt the full-body virtual staff helps me to find an item EASIER than following the navigational graphics** *
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

28. **Comments:**

   _____

29. **I felt the full-body virtual staff BLOCKS my view** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

30. **Comments:**

   _____
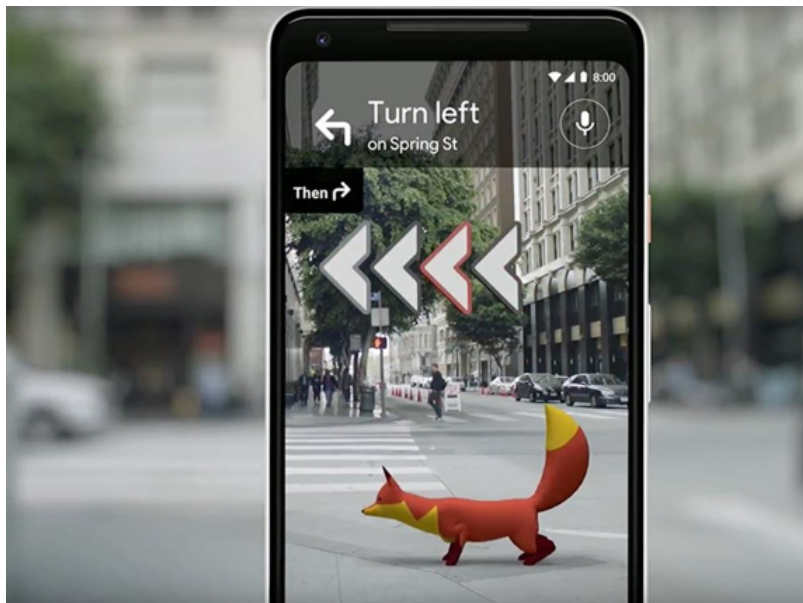
31. **I LIKE having the full-body human or animal form as a virtual assistant** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

32. **Comments:**

   _____

Thank you! :)

A.6   Post - Study Questionnaire

Participant #:	
Date/time	

Post-Study Questionnaire

This user study is part of Lam Kim Khoi's Master Thesis work

Please indicate your reference by circling a number on the scale. Also, please add comments if you would like to elaborate on your answers.

1. In general, I felt the user interface looks MORE COMPLICATED in the:

    3   2   1   0   1   2   3

Graphics app   *Virtual assistant app*

Comments:

....

....

....

2. I felt MORE INFORMATION OVERLOAD in the:

    3   2   1   0   1   2   3

Graphics app   *Virtual assistant app*

Comments:

....

....

....

1

3. I was CONFUSED while using the:

3　　2　　1　　0　　1　　2　　3

Graphics app　　　　　　　　　　　*Virtual assistant app*

Comments:

....

....

....

4. I felt it is EASIER TO FIND THE ITEM with the:

3　　2　　1　　0　　1　　2　　3

Graphics app　　　　　　　　　　　*Virtual assistant app*

Comments:

....

....

....

5. In reality, I WILL USE the:

3　　2　　1　　0　　1　　2　　3

Graphics app　　　　　　　　　　　*Virtual assistant app*

Comments:

....

....

....

2

6. I would RECOMMEND my friends and family the:

<div style="text-align:center">

3   2   1   0   1   2   3

</div>

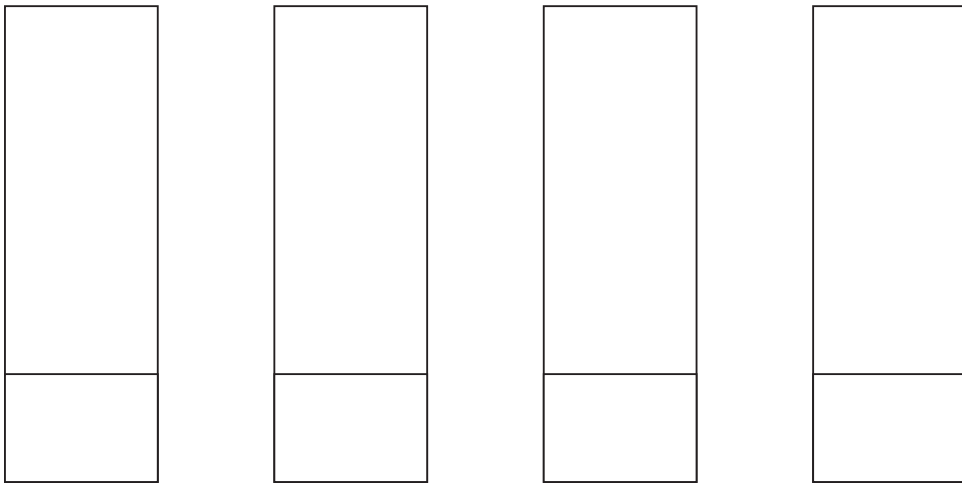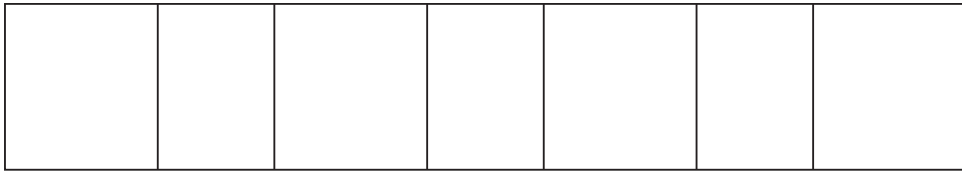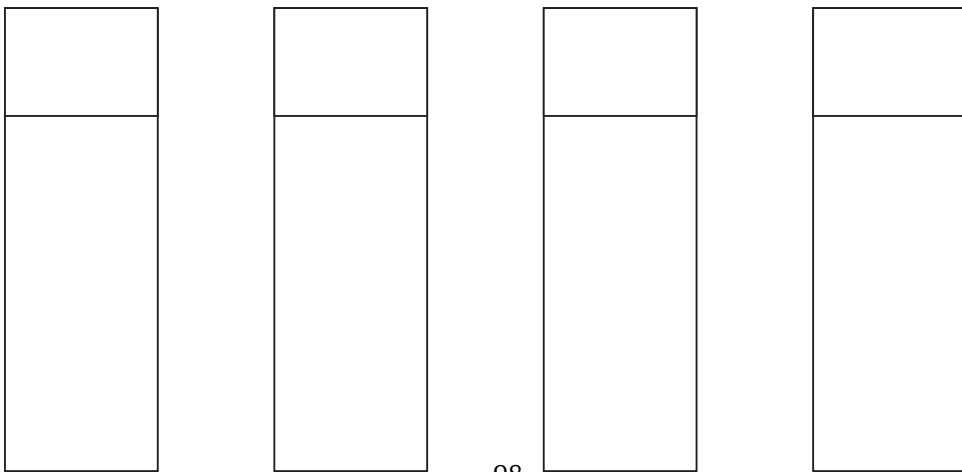*Graphics app*   *Virtual assistant app*

Comments:

....

....

....
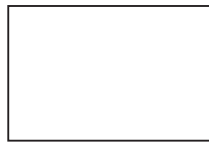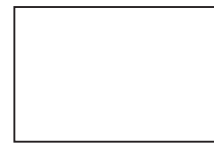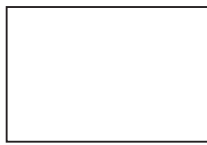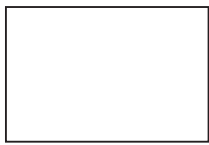
Thank you! :)

3

A.7   Floor Plan - Coop Supermarket

You are here

A.8   Floor Plan - Rema Supermarket

You are here

100
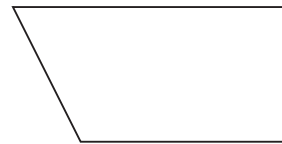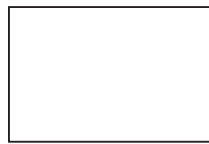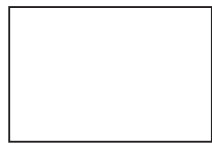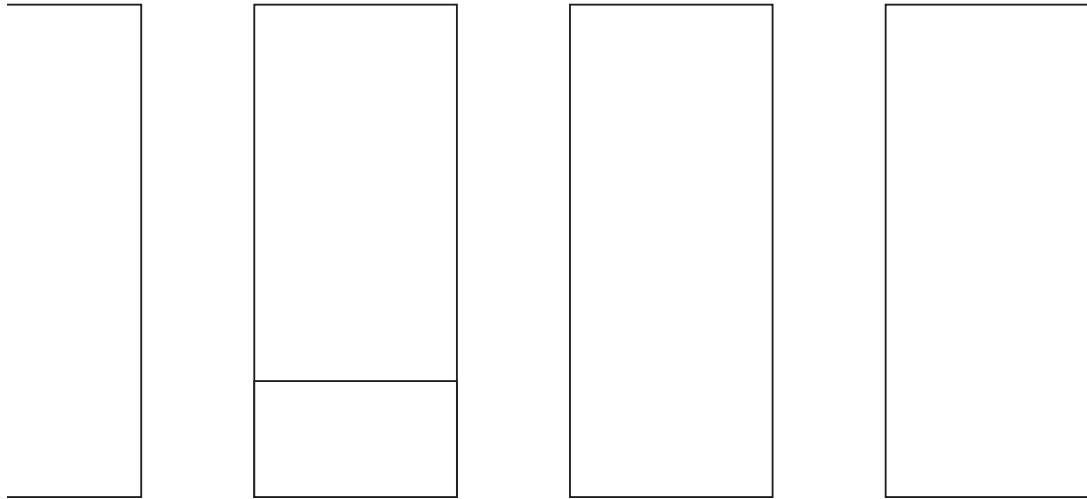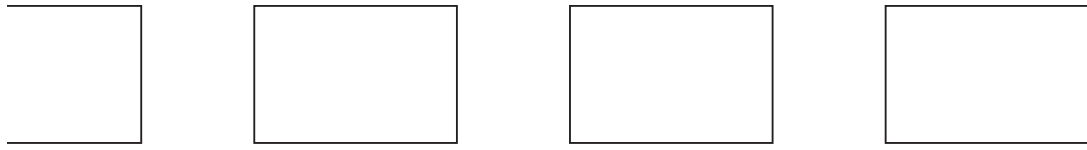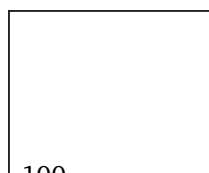
A.9   SPSS Data Results

```
COMPUTE GR_engagement=(8-NOTfuntouse)+IWILLusethisapp+(8-IdoNOTliketheinter
actionway)+
    WOULDrecommendthisapp.
EXECUTE.
COMPUTE VA_engagement=(8-VA_NOTfuntouse)+VA_IWILLusethisapp+(8-VA_IdoNOTlik
etheinteractionway)+
    VA_WOULDrecommendthisapp.
EXECUTE.
DATASET ACTIVATE DataSet1.

SAVE OUTFILE='/Users/frode/Desktop/khoi/Combined.sav'
  /COMPRESSED.
T-TEST PAIRS=GR_information_overload GR_effectiveness GR_engagement WITH VA
_information_overload
    VA_effectiveness VA_engagement (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

T-Test

Notes

Output Created		**29-MAR-2019 15:48…**
Comments		
Input	**Data**	**/Users/frode/Desktop/khoi/Combined.sav**
	Active Dataset	**DataSet1**
	Filter	**<none>**
	Weight	**<none>**
	Split File	**<none>**
	N of Rows in Working Data File	**37**
Missing Value Handling	**Definition of Missing**	**User defined missing values are treated as missing.**
	Cases Used	**Statistics for each analysis are based on the cases with no missing or out-of-range data for any variable in the analysis.**
Syntax		**T-TEST PAIRS=GR_information_overload GR_effectiveness GR_engagement WITH VA_information_overload VA_effectiveness VA_engagement (PAIRED) /CRITERIA=CI(.9500) /MISSING=ANALYSIS.**

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Notes

Resources	Processor Time	00:00:00.01
	Elapsed Time	00:00:00.00

[DataSet1] /Users/frode/Desktop/khoi/Combined.sav

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	GR_information_overload	12,0270	37	5,12882	,84317
	VA_information_overload	7,9730	37	3,75268	,61694
Pair 2	GR_effectiveness	16,7568	37	3,95394	,65002
	VA_effectiveness	19,3784	37	2,15189	,35377
Pair 3	GR_engagement	21,3514	37	5,33966	,87784
	VA_engagement	21,5946	37	4,99700	,82150

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	GR_information_overload & VA_information_overload	37	,355	,031
Pair 2	GR_effectiveness & VA_effectiveness	37	,576	,000
Pair 3	GR_engagement & VA_engagement	37	,401	,014

Paired Samples Test

		Paired Differences			95% Confidence …
		Mean	Std. Deviation	Std. Error Mean	Lower
Pair 1	GR_information_overload - VA_information_overload	4,05405	5,16906	,84979	2,33060
Pair 2	GR_effectiveness - VA_effectiveness	-2,62162	3,23481	,53180	-3,70016
Pair 3	GR_engagement - VA_engagement	-,24324	5,66375	,93111	-2,13163

Paired Samples Test

| | | Paired … | | | |
| | | 95% Confidence Interval of the… | | | |
		Upper	t	df	Sig. (2-tailed)
Pair 1	GR_information_overload - VA_information_overload	5,77751	4,771	36	,000
Pair 2	GR_effectiveness - VA_effectiveness	-1,54308	-4,930	36	,000
Pair 3	GR_engagement - VA_engagement	1,64515	-,261	36	,795

```
GLM GR_effectiveness VA_effectiveness
  /WSFACTOR=Effectiveness 2 Polynomial
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(Effectiveness) TYPE=LINE ERRORBAR=CI MEANREFERENCE=NO YAXIS
=AUTO
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Effectiveness
```

General Linear Model

Notes

Output Created		29-MAR-2019 15:55…
Comments		
Input	Data	/Users/frode/Desktop/k hoi/Combined.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	37
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.

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Notes

Syntax		GLM GR_effectiveness VA_effectiveness /WSFACTOR=Effectiveness 2 Polynomial /METHOD=SSTYPE(3) /PLOT=PROFILE (Effectiveness) TYPE=LINE ERRORBAR=CI MEANREFERENCE=NO YAXIS=AUTO /CRITERIA=ALPHA(.05) /WSDESIGN=Effectiveness.
Resources	Processor Time	00:00:02.61
	Elapsed Time	00:00:02.00

Within-Subjects Factors

Measure: MEASURE_1

Effectiveness	Dependent Variable
1	GR_effective ness
2	VA_effectiven ess

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Effectiveness	Pillai's Trace	,403	24,302[b]	1,000	36,000	,000
	Wilks' Lambda	,597	24,302[b]	1,000	36,000	,000
	Hotelling's Trace	,675	24,302[b]	1,000	36,000	,000
	Roy's Largest Root	,675	24,302[b]	1,000	36,000	,000

a. Design: Intercept
   Within Subjects Design: Effectiveness

b. Exact statistic

Mauchly's Test of Sphericity [a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon [b] Greenhouse-Geisser
Effectiveness	1,000	,000	0	.	1,000

Mauchly's Test of Sphericity [a]

Measure: MEASURE_1

Within Subjects Effect	Epsilon [b] Huynh-Feldt	Lower-bound
Effectiveness	1,000	1,000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

   a. Design: Intercept
    Within Subjects Design: Effectiveness

   b. May be used to adjust the degrees of freedom for the averaged tests of significance.
    Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F
Effectiveness	Sphericity Assumed	127,149	1	127,149	24,302
	Greenhouse-Geisser	127,149	1,000	127,149	24,302
	Huynh-Feldt	127,149	1,000	127,149	24,302
	Lower-bound	127,149	1,000	127,149	24,302
Error(Effectiveness)	Sphericity Assumed	188,351	36	5,232	
	Greenhouse-Geisser	188,351	36,000	5,232	
	Huynh-Feldt	188,351	36,000	5,232	
	Lower-bound	188,351	36,000	5,232	

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Sig.
Effectiveness	Sphericity Assumed	,000
	Greenhouse-Geisser	,000
	Huynh-Feldt	,000
	Lower-bound	,000
Error(Effectiveness)	Sphericity Assumed	
	Greenhouse-Geisser	
	Huynh-Feldt	
	Lower-bound	

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Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Effectiveness	Type III Sum of Squares	df	Mean Square	F
Effectiveness	Linear	127,149	1	127,149	24,302
Error(Effectiveness)	Linear	188,351	36	5,232	

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Effectiveness	Sig.
Effectiveness	Linear	,000
Error(Effectiveness)	Linear	

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	24156,338	1	24156,338	1606,964	,000
Error	541,162	36	15,032		

Profile Plots

Estimated Marginal Means of MEASURE_1

Error bars: 95% CI
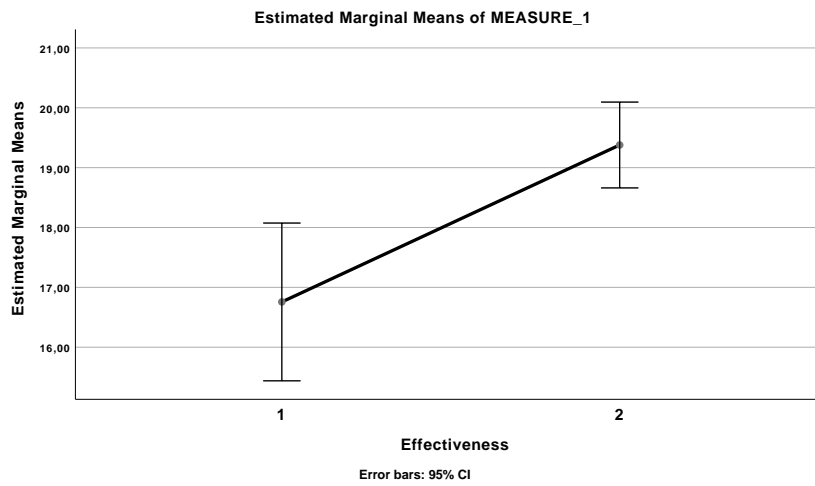
```
DATASET ACTIVATE DataSet1.
```

A.10   Feedback of Graphics App

Feedback of Graphics app		
Questions	Negative/Neutral	Positive
Q01: I feel that there is TOO MUCH information to manage in this app	• I wish there would be just the information which is close to my position. If I wish to go to a specific point I would use the search bar • I did not notice the product search function at first as the product categories took up a lot of attention • The labels were fairly large which is good for visibility but they were all colorful and bright which was distracting and I think part of the reason why I did not notice the search option originally • Yes, and now. It`s because the shop is already really crowded with stuff so it's a little bit hard to see the arrows in the beginning screen • A nice balance of information, though I think that the first screen can be a bit overwhelming for some	• It generally seems fine • There're quite a few buttons, but not too many • Just the right amount (not an overflow, but enough to find what you need) • It is pretty straight forward
Q02: It was EASY to input the item that I was looking for	• It might be easy - but I chose to just explore the shop without direct input (can I scan the product?) • This gave me choices that I don't think was necessary, probably because I didn't immediately find the search option and selected snacks instead. This therefore didn't lead me to exactly where I wanted • My initial way of finding the product with the app was unsuccessful, because I was not aware I could search for	• Yes, with the search bar it works well • The arrows on the floor made it easy to find the way

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	the product directly. Instead I found the general snack section • I completely overlooked the search field; however, I rarely ask for stuff in stores I prefer looking until I can find it, within reasonable time • It is easy to understand, maybe for me the search function was a little hidden • Not when just clicking on "snack" • I didn't notice the search bar at once because the categories are in my focus, maybe make a button to choose categories next to the search bare to avoid this. At the same time, it is easy to interact with it when you know about the features	
Q03: The user interface is CONFUSING	• The icons and buttons have similar colours which is a bit hard to distinguish - maybe too many colours. Also, the search bar I saw later in the prototype. If I would have seen it in the beginning I might have used it to find the product • I am not sure how clear it will be in smaller screens • The general categories were helpful, but it is also possible to do it by sight in a normal sized store • The design of it made me not notice the search option originally • Maybe a different background for the first menu or different layout would be nicer	• It would be very easy to get used to • Very clear what you can do, either you want a more general guide or to find a specific product

	• The buttons on top distracted me from realising there was a search bar on the bottom left of the screen. However, I do not think the buttons themselves were confusing, they just did not provide the accuracy I required for the task • With the store as the background, it will easy get much information at the same time	
Q04: The information on the screen is EASY to understand	• snacks = snacks + chocolate + cookies? • It was easier to find the product once the app had guided me by the product • Different layout would help it understand easier	• Looking back on it, it is quite clear what each of the buttons do in the application • For when the animations happened on the "floor" and not on the top of the screen • Simple with the arrows showing the way, and the title of the product over the product when you got there
Q05: The organization of information in this app was NOT clear	• I know it's extra, but I don't really remember whether there is a title for the organization or not, but would be clear after two or three uses • I think the search bar could be a bit more visible, because all the colorful buttons drew my attention immediately	•
Q06: I COULD find the exact location of a specific product using this app	• The flashing of the name of the product makes me not sure if it was flashing directly over the product, next to it, below it, or above it • With the search functionality I believe I could find the desired	• Yes, following the guide of the app helps

	product fairly easy. The only confusion could come from where the label above the product is at the end, if the products look similar • Found it with searching, but could be useful to have subcategories as well under snack • Because I did not use the search function. I used the category, I got more in the general area of the product	
Q07: I felt that it was NOT easy to complete the task with this app	• By clicking the categories "snack", it doesn't lead me to the product, but I guess if I using this app, I will start to search the item there, but still, it will take a bit more time; second try with the search bar is easy and clear for me, to find the exact item • I'm not sure if I could complete the tasks using only the buttons as I did in my initial approach • Maybe the search option should be more elevated if the goal is to find specific products that customers often ask for. On the other hand, the more general focus really guides you through the store, and it's not every time you know exactly what you are getting	•
Q08: I was able to find the item using this app with LITTLE effort		• Yes, especially with the search bar • The search bar allowed me to find the product quite easily by guiding me through the store • An easy search found the product

Q09: I felt this app is NOT fun to use	• The initial screen felt busy which was distracting	• I liked the green arrows on the ground they are fun • Fun? it has a generally friendly character about it • Seems like a handy app if you are in a new bigger store and is unable to find employees to ask • I think it makes grocery shopping a lot more fun
Q10: I WILL use this app in the reality	• I would like to try - but I know that those kind of AR apps using a lot of battery so I would avoid. If I could use a tablet provided from the supermarket, I would • It depends on whether I will have enough data(4G) or not; and also if my phone have enough memory to install it • I think I would be more likely to use the other one (VA app) • Depends how well I know the supermarket I am in. If it is a supermarket I am not familiar with, I would probably use it, especially if I am in a hurry, or something like that • Maybe if I struggle finding one specific thing • Could be interesting if the domain of the app was slightly different stores like Clas Ohlson, or maybe maps in general (Google Maps-ish)	• I think I would prefer having this application as opposed to asking an employee for directions, as long as the application is up to date on the locations of the products in store • When you are in a new store or they have moved thing. This app would be helpful
Q11: I do NOT like the interaction way of this app	• I think too much information or signs popping up • I prefer the first prototype (VA app)	• Felt pretty straightforward, which I like • It is easy to navigate

	• Some aspects (as I mentioned previously) were distracting • I learned that after all, voice input might be better, unless I could use some hand gestures to control the options	
Q12: I WOULD recommend this app to my friends and family	• I would recommend to people who have problems and can't find items fast. Some people just want to get shopping done. I personally like to go through all the rows and find new products and items I haven't thought about. Also older people who are not used to AR might have problems and like to talk to real person • Depends on the friend and the age of the one I recommend it too	• I would rather recommend this app to friends and family because it is not that different from most apps (the other prototype with the virtual assistant seems more different) • I would be interested to see where this goes • I believe most of my friends would either be using it already or too old and stubborn to try new technology

A.11 Feedback of Virtual Assistant App

Feedback of Virtual Assistant app		
Questions	Negative/Neutral	Positive
Q01: I feel that there is TOO MUCH information to manage in this app	• The text from the assistant could stay longer • May not need voice guidance such as "please follow me"	• Very easy to use and requires minimal interaction to work • Very clean and looked easy to use • Just enough information for me to complete my task • Simple and good • Very straight forward to start shopping
Q02: It was EASY to input the item that I was looking for		• I simply had to say what I was looking for and the assistant found it for me • Really easy with typing, which I prefer • The shopping assistant helped me to find the product I was looking for right away, and it was easy to navigate through the store with the lines on path that the assistant provided me
Q03: The user interface is CONFUSING	• I would prefer to be able to use the app in portrait mode. Also, it wasn't clear on how I could initiate a conversation with the virtual assistant	• It went straight to the point by asking me what I was looking for, so that I did not have to use much of the user interface at all • Very clear and understandable • It is easy to see if the assistant is guiding me towards the product I am looking for or if some words were lost in translation and I have to repeat the product that I am looking for
Q04: The information on the screen is EASY to understand	• It does not show a direction like arrow or fading • The blue color used might be a little too light for those with color deficiencies or in	• The direction markers on the floor seemed fairly easy to follow • It was easy to understand where the goal was located

	• some stores that use a lot of blue tones • Maybe make it more as arrows on the floor	• I really like the path that the assistant is suggesting
Q05: The organization of information in this app was NOT clear	• I would like to have feedback on my approach to the goal	• Once I got to the location it was very clear • Everything seemed quite clear and straight to the point to complete my task • I like that the assistant is asking you "what are looking for", this will make it easier for elderly people or kids that are not good at reading to use the app
Q06: I COULD find the exact location of a specific product using this app	• One thing is that the blue down arrow, I did not see it at first. So, for me that needs to be more distinct so that it is easy to see.	• I saw bacon sausage but well enough • I found the section where all the products of this type were • With the help of the assistant we located the exact location
Q07: I felt that it was NOT easy to complete the task with this app		
Q08: I was able to find the item using this app with LITTLE effort	• I think a little more effort is required to hear the assistant rather than just relying on visual information	• Talking to your phone in a place like this can be a bit scary, so I am happy there is a search by text option as well • I don't have to type the specific flavour • Only some typing required made it very easy, I think it would have been the same for voice commands
Q09: I felt this app is NOT fun to use	• It was fun the first time, but if I was using this every day then it might become less fun • It was helpful, but I'm not sure I would use the word fun to describe it	• I like the woman • Made finding much more fun • It makes less frustrating to find products in a store that you are not familiar with. I would like to use

	• I don't like assistant talking to me in public places, I would prefer to only get the info textually and only typing to get the info. I could possibly listen if I was using some Bluetooth headphones • Felt it is fun to use, but I would not use the virtual assistant in public because I think it will be too much noise. Also, I don't like to voice out to everyone at the store what I am buying	an app like this because it will save me time
Q010: I WILL use this app in the reality	• My phone has not much space - I wouldn't download • I am choosing 6 (points) but not 7 since it will probably be awkward to use the virtual assistant • I prefer to see employees in stores that can help with customer service • It depends on whether will I have enough data or not; and whether the App is too big for my phone • For me, I would prefer the Graphics app as it is a little bit more straightforward and does not require me to listen or optionally speak to the phone. The markers on the floor for the other app was also preferable • It is useful when you are at a new supermarket. But I know where most of the items in my local supermarket is, and would not need such an app for where I normally shop. But I would use it if I went somewhere new	• Saving time at the supermarket is something I would like

	• Not sure if I would use the voice command function, but maybe if I got used to it • Depends on the options in the app, if voice can be disabled. Additionally, I would like to be able to customize the image of the assistant, or simply have an animated shape indicating output • I would use, but I would not use the virtual assistant in public because I think it will be too much noise • Depends if I am familiar with the store or not. Might be helpful in a store I haven't been to before	
Q011: I do NOT like the interaction way of this app	• I think the navigation and user mapping of the device to be novel, but maybe serve the business more than the customer need • I found the voice slightly creepy or unnerving • I am personally not a fan of having to listen to a personal assistant • May be quite "heavy" with voice over and guidance signs to find a simple item • I am not a fan of voice interactions (they feel awkward) • Talking in public to a mobile phone could be a bit embarrassing depending on which product you are looking for • Personally, I don't like to talk to my phone, and I'm not a big fan of objects talking to me • It would be nice if I could query for a list of products • Typing is cool	• I do very much like the text interface • Easy to understand the buttons, and the conversion of the animated face made it fun and easy

	• I prefer the other one (Graphics)	
Q012: I WOULD recommend this app to my friends and family	• It may take something away from the shopping experience. I enjoy impulse selections and seeking good prices and deals. I'm not always rational in what I buy, and wonder if this will lead to mega scale markets with fewer attendants • It may work better for others than it would for me • Depends on the level of need	• Yes, if they were struggling to find their way around the supermarket • I think I would struggle to convince my friends and family to use an application that requires voice, but if textual search is available it should be alright • Maybe older persons • Depends on the person, and the age of the person. Might be good for elderly people, if they learn to use it • It would be like have you tried this app, you can talk to it and everything • Only if they have trouble finding stuff
Q013: I felt to include the virtual staff walking in front of me is UNNECESSARY	• What is the point of that • Simply having markers on the floor is enough for me • I think the line is less distracting and a bit more clear • I am a pragmatic person and don't see the added benefit of it • I prefer the blue line over the assistant walking in front of me. For some reason I feel that it is more clear and easier to follow • It's kind of feels like I'm a young child being dragged around by my mother. They would also be a bit in the way if I were looking for multiple products at once. I would however think they the assistant would plan the	• No since it feels more like real life than a cold lifeless computer • It might be helpful for older people • I think it's cool and maybe a bit better than just the lines, as they could be a bit confusing. I do think though that it's maybe be over complicated. But i reckon a lot of people would enjoy it, as it's a cool feature

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	most efficient route for me depending on my shopping list, then it would not matter if they were in front of me or not • I don't like that the assistant takes the form of a human, would prefer a glowing wisp or something similar • I don't know, if the store is busy I think it will be hard. I think I need to test it out. But for know I am thinking that I don't need that • It's a cool feature, but I felt that the pop-up "head" with arrow indicators was enough • With the first prototype, I can choose to make another path if I think that that path is better	
Q014: I felt the full-body virtual staff helps me to find an item EASIER than following the navigational graphics	• Clip was to short • It's a little bit different, but not much • It would have no effect for me • The line was easy enough • It all depends on how accurate each approach is in terms of pointing towards the product. If they cover up the product by being there I would prefer an arrow instead	• I will not lose track of path with person in front • For me a regular map with live position would be better, however some people do not handle maps well so this feature would be quite prominent for them • I agree on this point, as I previously stated that I think the stripes on the floor was not the best. I do think that arrows could have done the job, and the full body was a bit better • I feel that I can, but I am also worried for the staff in the store losing their jobs. But from a customer's point of view, then you don't need to look for a person. It it's

		better than the navigational graphics • It doesn't matter if I have a physical body to guide me through the store, but for an elderly person this would be a great option
Q015: I felt the full-body virtual staff BLOCKS my view	• I don't like her anymore • I prefer with the clear "line" in front of me • I am not sure if I would hold the phone high enough in public to see the assistant. I feel uncomfortable walking around with my phone in front of my face • Yes, I do think it can get in the way, and I would be a little afraid of crashing into someone or something. I also feel it would require me to look at the screen more (maybe constantly), whereas the navigational graphics, I would just need to look down a few times (because I can remember which way the line is going for a short amount of time) • The virtual staff could be in the way for other products I'm looking for or other people or unknown entities in the store. I would be scared to walk into someone directly if I were just staring at my phone, since I cannot know what is behind the virtual staff unless they are transparent • could be better to have the virtual staff semi-transparent • It depends on how she/he stand when they show you the product • Just a little bit	• I don't think that, as it really only would be the same as if a person was walking there in front of you

Q016: I LIKE having the full-body human or animal form as a virtual assistant	- It would be really fun but I think it's too much for a navigation app. Since it should help in a serious way it is not that helpful, precise information is more helpful - I guess it depends on the place, if it is crowded then might not be good to have assistant in full body form - Human/animal display not needed for way showing/navigation - I like the animal better, because it is smaller, and makes the app more fun. But I still think the graphical navigation is the best - It is not something i need, like with Pokemon GO. I had the AR on for the first day but quickly turn it off. It was more distracting though it was fun in the beginning. And sometimes I turn it on again, just for fun - A person is more realistic. A worker in the store	- The fox is much better than the old lady - I feel like it is a gamification of something routine - At first, I feel with the women in front of me is not necessary, it will block my view, but this image, with this little cute fox, I start to thinking, maybe have something small and cut creator will help? Users can choose different kind of creators based on their mood, and it will have a stronger memory link with the unfamiliar place - I think I would accept a small animal easier than a full body human as a VA - I think an animal would work better as it does not block your view as much - Animal would be way more fun and would not block the view - An animal could make it more fun to walk around, whereas a humanoid character could be a bit creepy/uneasy - If it was a smaller animal, but not a person - I would prefer a fox over a human - I think both are great, and maybe it would be even more fun for the user to have an animal showing the direction. This would also take up less of the screen, making it easier for the person to see. I think, as shown in the picture, that a fox would

		be great as it gives you more of a view, and it's also a fun way to illustrate the directions • Including a full-body virtual assistant could perhaps be less "intrusive" (in terms of size on screen) if using a smaller model, or an animal • I don't need the full-body human but animal is fun because it is unexpected. Animal is more engaging, children may like more

A.12 Feedback of Preferences between Graphics and Virtual Assistant App

Feedback of Post - Study Questionnaire (Graphics vs. VA)	
Q01: In general, I felt the user interface looks MORE COMPLICATED in the:	• The Graphics app maybe a bit more complicated but it seems more functional • It took me longer to understand the Graphics app because I had to make sense of the information/categories first. The VA was asking me directly what I searched for and I just answered without even looking much at the screen
Q02: I felt MORE INFORMATION OVERLOAD in the:	• The information displayed did not feel like an "overload" in either app • More information was presented to me that also blocked my view. This will cause my eyes to focus between that information and the background/objects
Q03: I was CONFUSED while using the:	• Graphics app is slightly more confusing at first • Both apps are easy to understand
Q04: I felt it is EASIER TO FIND THE ITEM with the:	• VA - because you can directly say (or type) the product or the section "snacks", for ex • The Graphics app had better way makers • I prefer Graphics but it might be complicated with all the info to older people
Q05: In reality, I WILL USE the:	• I like the categories option and the search bar, it gives you more variety with the Graphics app • It's nice to have a pointer to a general area of the store • I prefer the VA. I can input the whole shopping list and she shows me where is the nearest, I don't need to go back and forth.
Q06: I would RECOMMEND my friends and family the:	• I'd recommend both since they fit to different personalities • My parents do not speak much Norwegian, so talking to a staff is difficult for them. It'd be easy for them by just following a line on the floor to find the product • VA - because it is more fun and more impressive technology • VA - it's clear, simpler, and easier to use • Based on simple interface and less input option, VA is better for family when they already have predefined items to buy • VA - I would recommend to friends who do not like shopping

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