Abstract

The following report represents the research, workflow and findings relating to development of an Augmented Reality application, meant as support for the mentally disabled. Research aimed to validate the potential of AR technology to be used as an assistive tool, by providing guidance and help users accomplish everyday activities. The scenario of making microwave popcorn was chosen as the base activity for research, and the AR application was primed towards portable handheld devices. A user-centered approach to design was deployed, in order for the finalized prototype to better accommodate the targeted user group, and to ensure more accurate test results. The application proved promising when presented to participants outside the targeted group, but findings fell short of accurately validating the hypothesis, due to a nationwide lockdown as a result of the COVID-19 epidemic. Nevertheless, preliminary findings remain valuable and further research into the topic is encouraged.

Keywords: Augmented Reality, User-centered Design, Assistive Technology, Activities of Daily Living, Mentally Disabled, Behavioural Learning

List of Abbreviations

AAL	-	Ambient Assisted Living
ADL	-	Activities of Daily Living
AR	-	Augmented Reality
AT	-	Assistive Technology
ATC	-	Assistive Technology for Cognition
AV	-	Augmented Virtuality
CAD	-	Computer Aided Design
CET	-	Cognitive Evaluation Theory
CPU	-	Central Processing Unit
HCD	-	Human-centered Design
HCI	-	Human-computer Interaction
HMAR	-	Handheld Mobile Augmented Reality
HMD	-	Head-mounted Display
ICT	-	Information and Communication Technologies
IoT	-	Internet of Things
IoMT	-	Internet of Medical Things
ISO	-	International Organization for Standardization
IT	-	Information Technology
LiDAR	-	Light Detection and Ranging
MAR	-	Mobile Augmented Reality
MARTA	-	Mobile Augmented Reality Technical Assistance
MR	-	Mixed Reality
NSD	-	Norwegian Centre for Research Data
PACT	-	People, Activities, Contectx of use, Technologies
PEU	-	Perceived Ease of Use
PU	-	Perceived Usefulness
REK	-	Regional Committees for Medical and Research Ethics
RV	-	Reality-Virtuality
SDK	-	Software Development KIt
SDT	-	Self-Determination Theory
UX	-	User Experience
VARK	-	Visual, Aural, Read/write, and Kinesthetic
VR	-	Virtual Reality
VW	-	Volkswagen
ZPD	-	Zone of Proximal Development

List of Figures

Preface

This master's thesis represents the final piece of a two year process within Multimedia and E-learning at the University of Agder. From the start, the main goal has been to utilize knowledge obtained in a practical manner, by identifying course synergies and developing a personal talent stack of value towards society. Starting with course MM403 to better understand user needs, and learning about the power of foresight in MM402. Acquiring pedagogical techniques throughout two E-teaching modules, and the potential of motivation in course ORG453 and MM501. Finally, learning to master software tools such as 3D Studio Max and Unity game engine in course DAT216 and MM401, as presentable platforms for the acquired knowledge.

The potential for Augmented Reality as an assistive technology, has been a personal interest from the beginning, and getting the opportunity to research the benefits towards healthcare has only strengthened this fascination. Although AR has been proven to be highly adaptable in various industrial segments, a personal challenge has been to present solutions that are perceived practical for regular use. One such area of adaptation might be as an assistive technology towards candidates with cognitive impairment.

All in all, despite several restrictions pertaining to progression and conduct during this project, the knowledge acquired and personal experience gained remain indispensable, and grounds for future research into the field of assisted living technology within healthcare.

Special thanks to supervisors Ghislain Maurice Norbert Isabwe and Martin Wulf Gerdes as well as Santiago Gil Martinez, Morgan Konnestad and Sondre Sanden Tørdal for their advice and contributions during this master’s thesis.

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May 27th, 2020

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Contents

1 Introduction

In recent years, interest towards healthcare technologies aimed to improve quality of life have become a hot topic for research and development, both within the private and public sector. One of the key drivers behind this push has been the current aging world society, where the demand for care has been taking a toll on the availability of healthcare workers. Most elderly prefer staying in their own homes for as long as possible, fostering a sense of independence through living normal lives within safe and familiar surroundings. But as their health deteriorates with age or due to other conditions, the need for support in one form or another becomes a necessity in order to get through each day. Naturally, this does not only apply to the elderly, but individuals of all ages suffering from various kinds of physical or mental conditions.

From the healthcare workers perspective, provided support and tasks may be as varied as they are plentiful, spanning from simple household chores to administering life critical procedures on their patients. Their job description may also pertain to a significant amount of responsibilities that goes well beyond any professional education acquired to qualify for their position. As a result, healthcare workers often foster patient activity during visits, as a preventive measure against health deterioration, by promoting exercise and encouraging patients to take personal initiative.

Recent technological advancements have set the stage for a wide range of assistive tools to promote more independent living, enabling users to keep to their schedules, monitoring their vital condition, helping them to perform tasks as well as to learn new ones. One such technology is Augmented Reality, enabling users to visualize information needed through a tablet or a smartphone. This report focuses on one aspect of AR utilization, and how the technology can be used to give a step-by-step guide on how to operate household appliances. The aim being to promote independent living and improve quality of life, as well as allowing caretakers to put more focus on their academic skills during visits.

1.1 Research Motivation

Augmented Reality has been one of many identified technologies primed for medical research, but the overall focus has been towards education and training purposes for professionals. Although the technology is now widely available, issues pertaining to cost, practical adaptation, utilization stability and overall usability may have prevented private healthcare adaptation thus far. Nevertheless, some research has been conducted on potential patient utilization for the intended purpose of empowerment, but data obtained so far have revealed mixed results[1]. This thesis aims at a slightly different approach, putting more focus on the user experience, and utilizing AR technology to better accommodate patients needs. Based on previous research and knowledge acquired throughout the master's program, motivation for the thesis pertains to providing a contribution to this research, whilst personally acquiring more knowledge on both technology and utilization potential within the healthcare sector.

1.2 Scope and Structure of Thesis

Narrowing the thesis scope required preliminary research into the field of healthcare, current available technology, and the potential for other assistive technologies to be more commonly embraced. The problem statement addresses the potential of Augmented Reality as an assistive technology, as well as a source of promoting behavioural change for individuals suffering from cognitive disabilities, more specifically Down's syndrome or related conditions. Based on preliminary findings, the hypothesis concerns such groups' ability to utilize the technology, and whether or not AR could aid them in their activities, thus having a positive impact in their lives and making them more self-reliant. A specific use case was chosen as the basis for the thesis, involving the activity of making microwave popcorn safely and reliably through guidance provided by an AR application. Hypothesis and Research questions were structured in such a way as to validate users ability to utilize the needed technology, as well as conducting the specific step-by-step tasks of making the microwave popcorn.

During project progress, certain limitations became apparent, relating to both technology and utilization, as well as opportunities to perform user tests during an ongoing global virus epidemic. As a result, some theory elements have not been referenced directly and adequately throughout later chapters as intended. These and other limitations are described more in detail throughout the methodology chapter, with reference to both cause and how they limited the research.

1.3 Goals and Expectations

Although the main goal for the research project aimed to prove the hypothesis through questionnaires and prototype testing, a complementary goal involved focusing on creating a user-centered design during development. As a result, the final design could be optimized in such a way as to reinforce chances of successful conduct during utilization. Furthermore, tailoring the experience toward user needs could result in a higher degree of perceived usefulness, encouraging users to continue utilizing the application beyond the master's thesis.

2 Theory

The following chapter highlights the main learning strategy related to this thesis, sensory preferences for learning, as well as relevant concepts supporting learner progression. Relevant technologies are also defined, and finally key concepts within the human-centered design process are highlighted and explained.

2.1 Learning Theory

Taking into account the broad range of learning theories offered, four foundational domains are usually considered as covering the specific approaches: behaviourist, cognitive, constructive, and humanist theory[2]. Although all theories provide different approaches, they all share important insights into what makes for effective and efficient learning. Typically, research and teaching involve a combination of theory domains, dependent on the actual content and scenario for learning. This report will focus on behaviourism, and how its broad principles differ from other main schools of learning theory.

2.1.1 The Behaviourist Learning Model

Behaviourism ranks as one of the initial learning theories developed, and considers learning to be a result of stimulation and reinforcement. The theory is initially associated with the work of psychologists Edward Thorndike and Ivan Pavlov[3], based on the assumption that learning is manifested by a change in behaviour, that the environment shapes behaviour, and that the principles of contiguity and reinforcement are central to explaining the learning process[4].

Behavioural experiments were conducted on animals, subjecting them to puzzle boxes for rewards. Psychologist and behaviourist Burrhus Frederic Skinner built on the ideas of Thorndike and Pavlov, presenting the term operant conditions in 1937, describing the process in which learning can occur through reinforcement and punishment[5]. In human terms, teachers aim to acquire specific behavioural outcomes from their learners through a defined set of learning objectives by introducing positive and negative feedback mechanisms. Success is assessed based on the achievement of behavioural outcomes predicted by the learning objectives.

Unlike Cognitivism, behaviourism does not account for participants' mental state, but rather achieving behavioural change. Neither does behaviourism focus on willfulness, creativity and autonomy of participants like constructivism, but only on reaching predicted outcomes. Finally, where humanism focuses on the participants' needs and self-direction, behaviourisms concern lie with learning outputs and following single events for stimuli response. Even though being a century old theory, and considered both inferior and opposite schools of learning compared to the other three, behaviourism still holds ground as an powerful force of learning[6].

Behavioural change through positive and negative reinforcement gained ground during the 1960s and 70s, as a practiced method towards destructive behaviour among mentally disabled patients[7]. The increased demand for practical working solutions shifted prior focus on causality to explain patient behaviour towards developing techniques of treatment such as “overcorrection” and “timeout”. Recent decades have shown a shift back to cause-based analysis, but developed techniques are still frequently practiced as means to achieve desired outcome.

2.1.2 Individual Development Through Scaffolding

The idea of scaffolding is a broadly used term, both as physical objects supporting construction, and a theoretical concept of aid when learning. It is a central part of social constructive pedagogy, and implies adding temporary support mechanisms within the development process. In learning terms, the concept originated with the works of psychologist and social constructivist Lev Vygotsky[8], describing a range of methods and techniques with the purpose of exploiting the Zone of Proximal Development (ZPD). Figure 2.1 shows Vygotsky’s ZPD model where knowledge is divided into 3 zones. While the inner zone illustrates knowledge learners are able to assimilate by themselves, the middle zone shows knowledge that can be acquired with assistance. The outer zone is unachievable, until enough competence has been acquired and potentially new or modified scaffolding bridges the gap. As with construction, scaffolding for learning is meant as temporary constructs, gradually modified or removed when knowledge has been assimilated, thus continuously achieving expected level of knowledge development.

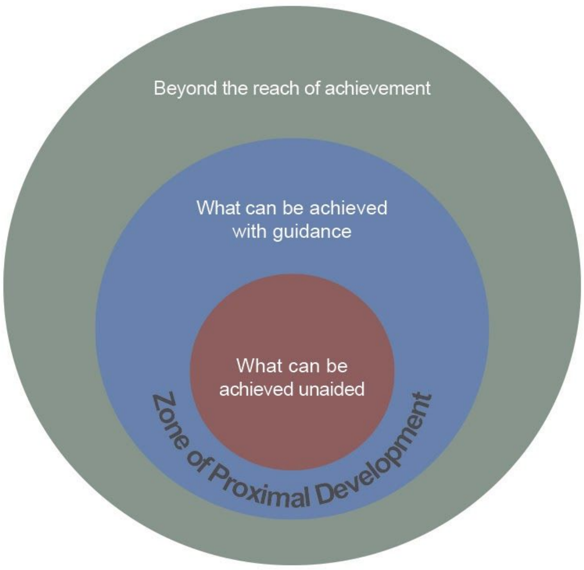

Figure 2.1: The Zone of Proximal Development[8]

Gordon Wells broadened the definition of ZPD to apply to ”any situation in which, while participating in an activity, individuals are in the process of developing mastery of a practice or understanding a topic[9]. The general idea being that ZPD can be applied to any form of skill, putting more emphasis on the guidance being the difference between assisted versus unassisted performance[10].

2.2 The VARK Modalities

Elements of the VARK model stems from the work of Neil D. Flemming and Colleen Mills[11], conducting questionnaires towards students in order to map their sensory preferences. Fleming and Mills suggested four modalities that seemed to affect the learning experiences between students and teachers as shown in figure 2.2.

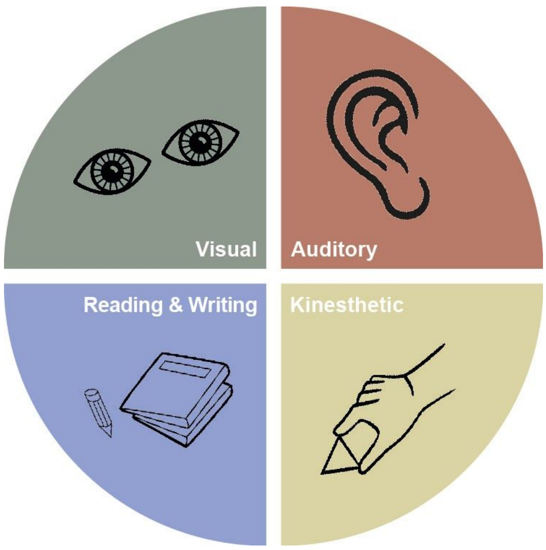

Figure 2.2: The VARK Model[11]

The visual preference pertains to graphical presentations such as maps, charts, diagrams, icons and symbols that represent wording rather than actual text. Aural, or audio presentation in general, describes information that is spoken and heard, such as lectures, radio, phone conversations, voice instructions and so on. As the third category implies, reading and writing represents all information displayed as words such as manuals, reports, essays and similar. Finally, the kinaesthetic category concerns preference of actual experience and practice such as demonstrations, simulations, animations and other presentable forms relating to real life. These four categories seldom operate distinct from each other, but rather overlap and accommodate one another according to individual preferences.

The VARK model has frequently been adopted to assess learning styles. One such example is research done by Tilanka Chandrasekera and So-Yeon Yoon[12], involving how preferences affect AR and VR utilization and the creative design processes. When considering the kinaesthetic and visual category of the VARK model as to perceived usefulness (PU) and perceived ease of use(PEU), Chandrasekera and Yoon concluded that learners preferred the AR environment over the one presented by VR.

2.3 Motivation

One critical component for reaching one's goals is some form of motivational drive. Derived from the Latin word movere, meaning “to move'', motivation creates a presence of purpose, and desire for personal achievement. Historically, the field of psychology explained that motivation originated from either basic biological drives such as hunger, thirst and sex, or the more extrinsic rewards and punishments. This simplistic perspective was later expanded upon, as observations showed both humans and animals engaging in behaviours that seem to be ends to themselves, rather than a means to specific outcomes[13].

Motivation involves a constellation of beliefs, perceptions, values, interests, and actions that are a natural part of everyday life, from choosing to get out of bed in the morning, keeping fit by exercising and paying bills on time, to being productive at work and helpful in the community. As a concept, motivation is used in many different disciplines to analyse reasons for human behaviour, acknowledged to potentially enhance or diminish individual performance and efficiency[14]. Whether the driving factor is personal interest, excitement, curiosity or more external driven, motivation remains an essential part of breaking the status quo and continuing moving in one direction or another.

2.3.1 Intrinsic versus Extrinsic Motivation

As the word implies, intrinsic motivation has an internal origin, projecting will and interest outwards towards the activity at hand, and doing so without any need for external cues or rewards. Harry F. Harlow coined the term after studying rhesus monkeys solving puzzles through pure self-gratification with no external incentives[15]. His work brought forth the notion of the third human drive, and the need for directing one's own life, learning, creating and outperforming expectations through inner motivation. Intrinsic motivation supports a meta-theoretical assumption by Professors Edward L. Deci and Richard M. Ryan, claiming that individuals have a natural desire to engage with their surroundings[16]. As pointed out by Deci and Ryan: “Intrinsic motivation involves doing an activity because it is interesting and enjoyable"[17], hence drawing motivation from what is conceived to be pleasure and self-rewarding activities. Given the right incentives, such as individual need for autonomy and competence, intrinsic motivation can be triggered and flourish. This is especially

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apparent within education, where results lead to deeper learning of academic content and better performance at heuristic tasks, as well as challenges requiring conceptual development and understanding[20].

In contrast, extrinsic motivation deals with external influences, and rely on incentives such as reward or punishment in order to affect motivation and promote specific behaviour. As an example, the “carrot and stick” theory, put forth by Jeremy Bentham during the industrial revolution, claimed that workers are self-interested, motivated by the desire to avoid pain or seek pleasure, thus will work only if the reward is big enough, or the punishment sufficiently unpleasant[21].

Both intrinsic and extrinsic motivation have their place of purpose, but the different source of incentives and rewards makes them hard to combine for optimal effect. Deci and Ryan claim that extrinsic rewards may in some cases maintain or even enhance intrinsic motivation, but more often than not the opposite becomes a reality, resulting in overall motivation being undermined[22]. Experiments seem to suggest that extrinsic motivators can be effective when the task at hand is more algorithmic based, with a clear set of instructions, and may be destructive when dealing with tasks of a heuristic nature when creativity plays an important role[20].

2.3.2 The Strive to Become Competent, Feel Related and Autonomous

In the early seventies, Deci and Ryan started working on their Self-Determination Theory (SDT), based on the prior research comparing extrinsic and intrinsic motivation and their influence on human behaviour[23]. A decade later, their first comprehensive statements on SDT were published in the mid 1980s[22], covering a wide range of human issues, among them personality development, self-regulation, psychological needs, goals and aspirations, energy, vitality and wellbeing. Since then, the theory has gotten a strong foothold with a steady increase in related studies published, especially within sports, education and healthcare. The theory states that humans have three inherent psychological needs that governs individual self-determination figure 2.3.

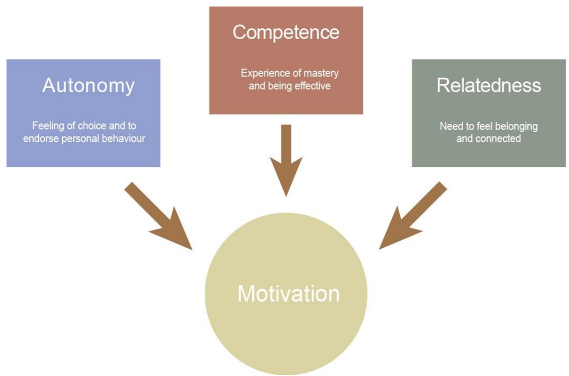

Figure 2.3: Self-Determination Theory[23]

The need to feel competent is essential to wellness, and the perceivement of being effective, as well as potentially mastering aspects of personal importance, strengthens this notion. Feeling autonomous in everyday life, creates a feeling of choice and self-direction, leading to a more wholeheartedly backed actions. Finally, the need to feel related and a sense of general belonging, both receiving from, and contributing towards others, creating a notion of personal relevance. Provided that these three needs are nourished and intrinsic motivation has the chance to flourish, individuals will freely seek out what interests them, whether it is labour or education or other.

Cognitive Evaluation Theory (CET), a subsidiary contribution to SDT, focuses on competence and autonomy, and how external influences or events affect the degree of intrinsic motivation. As an example, events and challenges that are perceived to promote a higher degree of competence will strengthen intrinsic motivation, whilst those that leave the individual feeling less able will diminish the degree of intrinsic motivation. Likewise, if external information or guidance are considered as assisting and helping rather than controlling and threatening towards individual autonomy, intrinsic motivation will either be enhanced or undermined[22]. As an example, in a research experiment[21], 3 groups of blood donors were separately given monetary compensation, a choice of charity to be sponsored or giving blood as a voluntary contribution. Results showed that instigating a more fixed and controlled transaction, rather than a choice of charity or free act of kindness, eventually resulted in reduced participation.

2.4 The Reality Spectrum

Conceptualizing “reality”, leaves room for a vast number of interpretations, many dependent on the context in which the word is to be defined. In terms of the real world, as opposed to a virtual environment, the former is constrained by the governing laws of physics while the latter only constricts the creators imagination and technical expertise. Cambridge Dictionary defines reality as “the state of things as they are, rather than as they are imagined to be”[24], while virtual reality is described by Merriam-Webster as ”an artificial environment which is experienced through sensory stimuli provided by a computer”[25].

Paul Milgram viewed the two concepts as laying on opposite sides of a spectrum, introduced as the Reality-Virtuality (RV) continuum[26]. This spectrum, as illustrated in figure 2.4, defines the relationship between real and virtual objects, and where different technological concepts are placed within the range. As the outermost left part of the continuum defines any real world environment, consisting of physical objects (either directly observed or indirectly presented through a window or video display), the opposite right end defines completely virtual projected environments such as computer based graphical simulations. Between the outer ends, the Mixed Reality domain (MR) offers a blend of these two states, related to their degree of virtual influence.

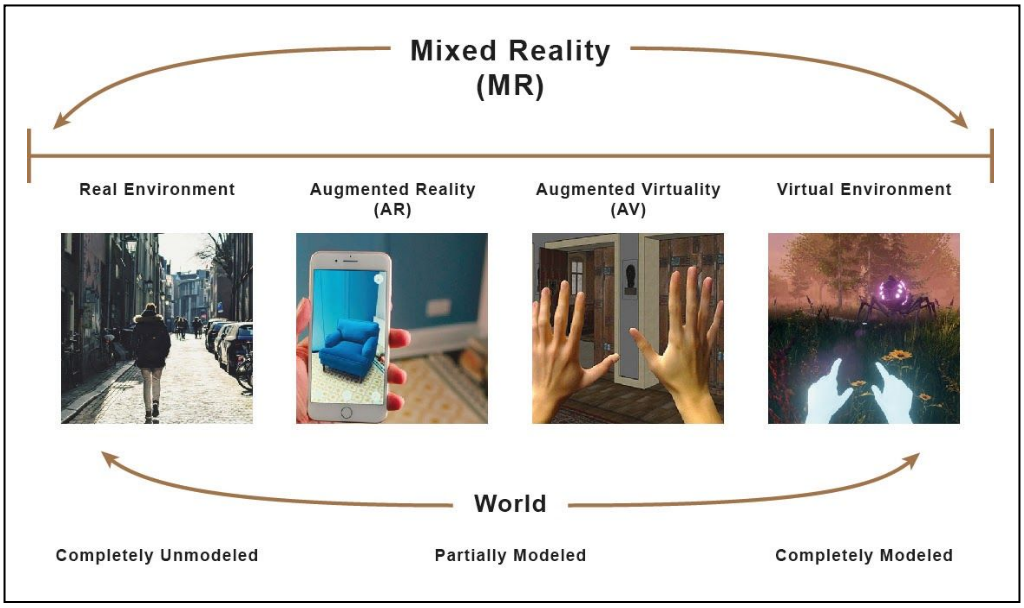

Figure 2.4: The Reality Spectrum[26]

This blended range of mixed reality is further broken down into Augmented Reality (AR) elements that supplement or blend graphical elements alongside the natural environment, and Augmented Virtuality (AV) where the augmentation is supplemented with real-time representations. In contrast to complete virtual environments, both AR and AV operate within the boundaries of real world environments, whether the case may be to simulate a virtual chair (AR) or produce graphical surface overlays (AV) as pictures in figure 2.4 illustrate.

Though there are clear distinctions between the two, both types of augmentation are often referred to with the common denominator AR. However, it is important to grasp the distinction and impact between the two, as well as the overall reality-virtuality continuum when developing augmented solutions, with the aim of being an immersive and beneficial experience towards users.

2.4.1 Virtual Reality Technology

Although VR and utilization has become an increasingly central topic for development these past few decades, the concept has related origins from prehistoric imaginary cave drawings, paintings from the middle ages and animated moving pictures, to modern industry and game development[27]. The term Virtual Reality became broadly known during NASA's utilization of computer-based simulations for space projects in the 1980s[28]. Since then, the technology has slowly gotten a foothold within other industries as shown in figure 2.5, due to both hardware and software development becoming more affordable and user friendly.

The virtual environment simulation, commonly provided by an enclosed head gear providing 3D computer graphics, immerses users into synthetic worlds that either aim to represent an existing or a fictional environment. At the current state of central and graphics processing units (CPUs and GPUs), simulations can project a high level of detail and realism, enhancing user immersion. Being on the far right of Milgram's RV continuum, users are completely locked out of their immediate surroundings, thus actual movement may be restricted to the correlation between the real world and the synthetic simulation. This lack of correspondence can result in loss of spatial awareness that may cause user sickness and nausea[29], and in worst cases personal injury if actual movement is obstructed.

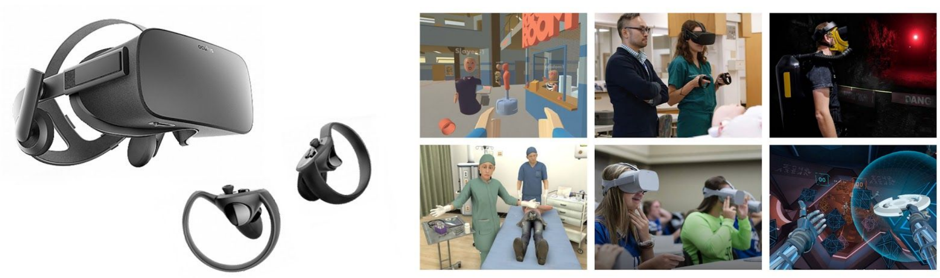

Figure 2.5: Oculus VR[30]

2.4.2 Augmented Reality Technology

In contrast to an enclosed virtual environment, Augmented Reality technology supplements reality with graphical illusions, rather than completely replacing the reality users occupy[31]. The degree and form in which AR elements intrude within the real world through graphical overlays, determine the augmented classification according to Milgram[26]. As shown with VR, Augmented Reality also has a related history with various degrees of implementation. From television broadcast with text and graphical highlights to Hollywood movie creations where Mixed Reality creates enhanced and believable atmospheres where virtual and real objects coexist on the cinematic screen.

A more modern approach to AR given by Ronald Azuma[32], relating to specific technologies such as Mobile Augmented Reality (MAR) or Handheld Mobile Augmented Reality (HMAR), assigns the following attributes to be met to qualify as Augmented Reality:

1. **It should combine the real and the virtual**
2. **The augmentations should be interactive in real time**
3. **They should be registered in three dimensions**

Back in 1997, Azuma[32] explored six professional candidates for AR technology, spanning from medical visualization, maintenance and repair, annotation, robot path planning, entertainment, and military navigation and targeting. With the release of the open source ARToolKit in 1999[33], followed up by a vast number of alternatives and complementary software the past two decades (ARCore, Vuforia, EasyAR etc.), development has become more mainstream. The result being content creation by both professional and private enthusiasts, greatly supported by innovation within mobile platforms, covering a much greater span of utilization than suggested by Azuma.

Due to the highly accessible nature of AR through millions of handheld devices such as smartphones and portable tablets, new applications are frequently being developed and offered through digital marketplaces. Whether the intention is educational learning, an assistive tool or intended for leisure purposes such as playing Pokémon GO[34] or Harry Potter:Wizards Unite[35] (figure 2.6), the possibilities are practically endless.

Figure 2.6: Pokemon GO[34] and Harry Potter:Wizards Unite[35]

Users are free to navigate within the real world environment, and observe any graphical augmentations either caught on camera and displayed on a smartphone/tablet or projected on lenses when utilizing equipment such as Microsoft HoloLens[36] shown in figure 2.7. Augmented objects and surfaces remain stationary and naturally scaled within the real viewed environment.

Compared to VR, the AR technology is highly process intensive, due to projections being calculated in three dimensions and reacting to camera movement within the real world. Complex augmentations may result in high battery drain and thermal dissipation, making handheld devices both suitable and uncomfortable in use[37]. Specific points of reference are always needed in order for any augmentation to appear and position correctly. Reference points calculated through the optical camera and calculated by the software with no precise positioning data, can result in augmentations that feel jerky or drifts[38].

Figure 2.7: Hololens[36]

2.5 Assistive Technology

Throughout history, humans have relied on technology to assist or complement them in their daily lives. In 1877, German philosopher Ernst Christian Kapp defined such assistive technologies as a direct morphological extension of human organs[39]. As Bows, slings, and guns extend the ability to throw projectiles, chariots, bicycles and motorbikes in turn increase mobility. Canadian philosopher Marshall McLuhan[40], while studying the influence of communication media in 1964, expanded the definition to accommodate technologies which extended cognitive functions such as writing and printing, extending the ability to store information. In more modern terms, assistive technology also refers to digital equipment or software that aid users through challenges in order for them to learn, communicate, and become more self-reliant. These subset of devices, more related towards cognitive functions have been rightly Assistive Technology for Cognition (ATC)[41], referring to aids that are meant to extend human mental capacity and control.

Although assistive technology of cognition undoubtedly can be used as scaffolding to support users throughout their zone of proximal development, available devices may be costly, not universally accessible, nor tailored to individual needs. Aids can also hinder personal development, and be abused to the extent that utilization becomes an unnecessary addiction rather than necessary support. As an example, access and utilization of the internet through various hardware platforms creates both a portal into vast amounts of knowledge, but can also lead users down undesired paths of excessive usage, losing sense of time, neglecting basic needs, inducing feelings of anger or result in personal withdrawal[42].

This chapter focuses primarily on how AR technology is used as an assistive aid, both in the workplace as a guide and source for development, as well as ongoing research into how this

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technology potentially can improve individual self-reliance and quality of life among healthcare recipients. Even though this report focuses primarily on AR technology, it is important to note that current mobile devices, more often than not, are dependent on working in conjunction with several other assistive technologies. Through such intercommunication enabled devices, with various sensors for tracking and monitoring (referred to as IoTs or IoMTs), data can be collected and analysed, tailored and improved upon through artificial intelligence and machine learning[43].

2.5.1 Work and Training Practices with Augmented Reality

Looking back a decade, the thought of widespread deployment of AR technology within manufacturing would not seem to make much sense for many managing directors. But in recent years, both the potential and benefits are becoming clear, and utilization more and more a reality. In a recent review of studies and papers spanning from 2006-2017, published by Eleonora Bottani & Giuseppe Vignali[44], the conclusion was that interest towards use of AR technology for industrial purposes was increasing. 174 studies were analysed, divided into review, conceptual, technical and application papers, with the amount produced gradually increasing throughout the 11 year period. The majority focus of application have been towards manufacturing and machine tool industries, involving assembly, maintenance, product design, and worker training. Other areas of application, such as safety, ergonomics and remote collaboration are emerging, but not yet fully explored as to the overall potential.

Back in 2010, auto manufacturer Volkswagen started introducing HoloLens AR technology in their service training centres. Their augmented virtuality solution superimposes a digital layer on top of their vehicles, in order for their service technicians to train and perform auto repairs. The success of the application resulted in the company rolling out the MARTA application (Mobile Augmented Reality Technical Assistance) towards their service centres, where step-by-step animations show the procedures on a tablet when pointed at the correct location (figure 2.8). More personal consumer applications may soon follow by other developers, enabling personal repairs possible for car owners themselves [45]. The success has led to AR technology being implemented in other departments at Volkswagen. Project teams of designers and engineers are now collaborating on future concepts, assessing prior graphical designs and technical information, and creating new models in real-time through the use of head mounted displays (HMDs)[46].

Figure 2.8: Utilization of AR technology at Volkswagen[46]

2.5.2 Ambient Assisted Living with Augmented Reality

The term Ambient Assisted Living (AAL) is derived from traditional Assistive Technologies as a field focusing on technology for people with disabilities. The aim is a practical “design for all” solution in regard to usability and accessibility, coupled with emerging Ambient Intelligence technology, where artificial intelligence responds and adjusts to individual needs. These technologies range from quite simple devices such as intelligent medication dispensers, fall sensors or bed sensors to networked homes and complex interactive systems[47].

One major driving force for adapting this technology is the current aging world society, where the number of old age individuals have tripled over the last fifty years, with a forecast of matched increase over the next half century[48]. Global cost of care is becoming unsustainable[49], as such provisions are required to support activities of daily living, such as dressing, mobility, personal hygiene, shopping, and food preparation[50]. In order to counteract the effects and demands such a paradigm shift puts on the healthcare system, research has been focused on prolonging autonomous living for individuals with the goal of higher self-reliance.

Individuals with cognitive impairment constitutes a priority field in this regard, dealing with various forms of dementia, stroke, mental illness, acquired brain injury and intellectual disability. A research trial project, involving AR technology on patients with Alzheimer’s disease, was conducted at the Technical University of Munich in Germany in 2019[51]. The aim being to introduce cues, through audio and different visual stimuli, to perform operations involving making tea, testing usability and feasibility to provide directions for further improvements. Microsoft HoloLens was introduced to a group of 10 participants, projecting a 6 step procedure consisting of three-dimensional dislocated and floating dynamic holograms (figure 2.9), maneuvered interactively through hand gestures, voice commands or a clicker (similar to a computer mouse). According to Milgram's Reality-Virtuality (RV) continuum[26], such projections would be considered as Augmented .

Reality, and on the middle-left side of the spectrum. All participants conducted the task twice, with both the HoloLens and making tea without assistance as grounds for comparison. The AR application was developed within a user-centered design approach, consisting of four iterative cycles (March 2017 – December 2017) through collaboration between researchers, clinicians, patients and family members in the framework of the EU project “Therapy Lens”[51]. Trials were timed and monitored, and semi-structured interviews were conducted with each participant upon completion.

Figure 2.9: HoloLens trials conducted by the University of Munich[51]

During trials, participants committed errors both with and without holographic assistance when executing the task, with no significant differences in success rates or error frequencies observed. Three of the participants were unable to successfully utilize HoloLens, failing to correctly mimic the steps provided by the application, thus failing to complete the task. Patients with more severe problems performing the task unassisted, showed lower increases in trial duration when assisted with AR.

When interviewed on acceptability after trial completion, participants were overall positive towards the AR application, and appreciated the several forms of input (visual and audio cues) helping them to avoid misunderstanding the intended procedure. However, there were still noted confusion in regards to performing the different steps, and complaints with the large and uncomfortable head gear utilized. The overall conclusion of the project was that the acceptance of assistive technology, such as the Microsoft HoloLens, is expected to vary depending on individual conditions of dementia and its progression. Recommendations for future trials involved re-evaluating the different steps and their presentation, as well as involving participants at an earlier stage of development, in accordance with references literature review on technologies to support community-dwelling persons with dementia [52].

2.5.3 Human Factors and Ergonomics in regards to Assistive Technology

A significant challenge when developing and implementing Assistive Technology for Cognition is the consideration of potential individual human factors involved. Issues can arise in regards to novelty and/or complexity of ATC for users with cognitive impairments[53], context of use such as at home, at work or in an institution, and general user needs may pose new challenges and also change over time. ATC have yet to achieve greater potential in this regard, struggling with challenges of mismatch between users' cognitive profile and prescribed technology to meet optimized therapeutic effect[54]. Adaptive intelligent systems, with the utilization of artificial intelligence, may provide a solution to users evolving needs and utilization conditions. User involvement during development of adaptive systems has provided better contextual understanding[55], but participatory methods for designing adaptive and tailored systems remains largely unexplored. Due to the complex nature of potential utilization scenarios, such systems would be expected to adapt accordingly.

Another aspect involves ergonomics, and whether the technology platforms utilized are practical in relation to users medical condition and environmental context of use. Potential challenges within ergonomics and the utilization of AR technology are clearly apparent. Handheld equipment such as smartphones and tablets may be highly mobile, but can hinder operators to manually perform tasks with both hands. HMDs may not pose the same problem, but could force users to limit head movements in order to achieve stable conditions for the technology. Some studies also suggest that users may suffer from decreased visual acuity while observing physical targets through head mounted displays[56]. The current state of comfortability of HMDs, experienced with Microsoft HoloLens during research trials[51], may discourage users from activities deploying such equipment.

2.6 The Human-centered Design

The human-centered design (HCD) process has continuously gotten a stronger foothold during the past few decades, shifting focus onto user needs, problems, desires and goals rather than purely focusing on general market demand. The HCD model, often referred to as “participatory design”, represents an ongoing process for development, where the end goal is solving users problems and helping them lead easier and more productive lives.

From an industrial perspective, in effort to standardize the process, the ISO 9241-210 have been proposed by the International Organization for Standardization[40], with revisions leading to the current ISO 9241-210:2019 Ergonomics of Human-System Interaction. The ISO standardization attempts to offer guidelines on how to problem solve human-system interaction (HCI), and uniform the definition of the user experience (UX). Figure 2.10 offers a procedural approach to improve the UX, through multiple iterations during development.

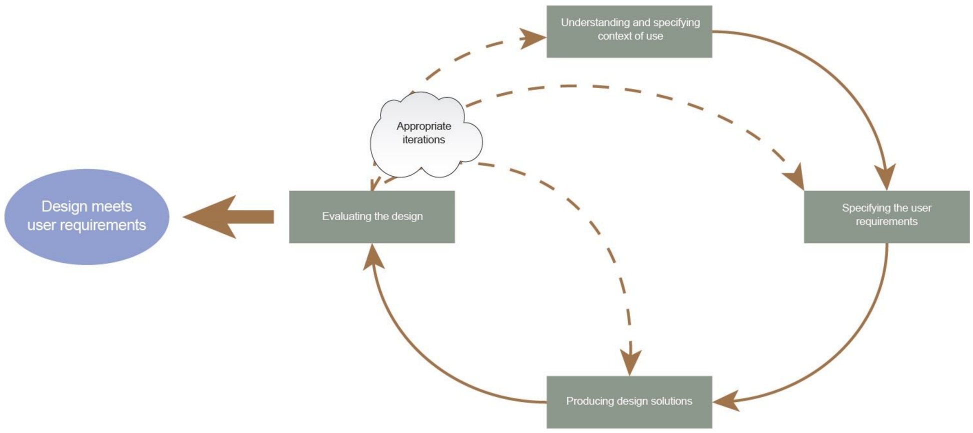


Figure 2.10: ISO 9241-210:2019 Ergonomics of Human-System Interaction[40]

As figure 2.10 illustrated, the process starts with understanding users' needs in the real world, and utilizing this knowledge to specify functional and non-functional design requirements in compliance with those needs. Design solutions are then created, based on the different requirement criteria, and tested with users for evaluation. User feedback is then evaluated up against current design, and potential iterations to the design are considered, creating a process loop until determined that the design has met sufficient aspects of user requirements.

2.6.1 The PACT framework

When developing a new design, whether software or technology based, the product should strive to accommodate individual needs within the intended group of users. Such endeavour can be referred to as an human-centered approach to development, and a frame of reference can be found in the PACT model. As figure 2.11 illustrates, the framework refers to People, their Activities and Context of conducting them, as well as the Technology utilized. Together, these four components help designers to get a perspective on important factors to keep in mind, and develop accordingly[50].

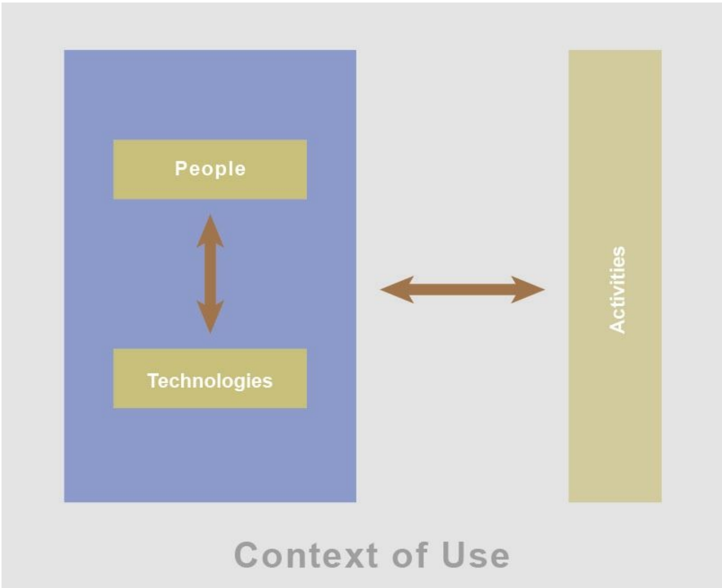


Figure 2.11: PACT Elements[50]

Knowledge of whom the stakeholders are, their physical and mental prerequisites, what activities they perform, the purpose and duration, activity frequency and composition, as well as safety considerations may all be important factors to consider. These considerations may also be linked to the physical environment where the activity is taking place, as well as the social context. Privacy considerations may have to be accounted for, both in terms of research and the final interactive product or technology, where concerns about input/output with systems and potential communication between users need to be addressed. Designers need to keep all these factors in mind when focusing on the user experience (UX), as they attempt to understand and develop products for their intended purpose[50].

2.6.2 User Experience Design

Having a human-centered design requires understanding the different aspects of user experience, and implementing accordingly during development and testing. One tool that provides more insight, and explains the various facets of user experience, is Peter Morville's honeycomb model[51] as illustrated in figure 2.12. Derived from an analysis of connections between business goals and context, user needs and behaviour, as well as content, the honeycomb presents six categories of user value, aiming to provide insight into key areas of a good user experience.

Figure 2.12: The Honeycomb Model[51]

According to the honeycomb model, the system utilized to present the product needs to be simple and easy to use (usable), and designed to be familiar and understandable with a comfortable learning curve. The product must accommodate user needs, in order to have a purpose (useful), as well as being visually appealing and easy to translate (desirable). Information presented should be easy to locate and navigate (findable), and make sense for the user. Design should aim to provide an equal experience (accessible) towards both the average users, users with disabilities as well as other user groups, and the providers of such products need to be perceived as trustworthy (credible).

Keeping in mind that designs will differ, based on the balance between context, content and users, so will focus on the honeycomb model and the priority and importance of each category. By outlining and defining all the areas of importance, designers can get a better understanding of what is essential to the user experience, thus helping to define priorities during development[51].

2.6.3 Design Principles

The heuristic evaluation method, initially proposed by Nielsen and Mohlich in 1990[52] and later modified by other researchers for specific system evaluation, represents a usability inspection evaluation checklist. The method applies knowledge of typical users, through the minds of experts within the field, guided by a set of usability principles known as heuristics. The experts evaluate whether user-interface elements, such as dialog boxes, menus, navigation structure, and online help conform with tried and tested principles, in order to identify usability issues[52]. Feedback given from such sessions constitutes grounds for product iterations until usability concerns have been addressed in a satisfactory manner.

Issues addressed in such sessions concerns how users access, learn and remember elements of the system through sufficient visibility, system consistency and familiarity with language and symbols presented. The properties of elements presented and how they are meant to be used (affordance) is also a priority, as well as overall system navigation and creating a sense of user control with appropriate feedback given during operation. Safety and security concerns are addressed, regarding how to quickly recover from actions taken and constraining the framework of the system to avoid inappropriate actions. Finally, playing on preferences, accommodating different user experiences to reach desired outcomes through flexibility, presented with a stylish and attractive design, presented in a pleasant and polite way (conviviality)[50].

Such evaluations are considered highly valuable during design, and frequent sessions may be needed, which may result in cost becoming an issue if attendees need to be compensated for their contribution. However, since this method does not require special facilities to be conducted, and each session is relatively short and inexpensive, it is recommended as an exercise to identify the majority of usability issues related to the design[52].

3 Methodology

This master's thesis, and consequently the method used to reach the final results, focused on the deductive approach[57], starting with identifying the problem, defining solution objectives, designing, testing and finally evaluating the findings. Thesis progress was planned and structured by utilizing Gantt charts, with both an executive version (figure 2.13) mapping the overall process with deadlines, and a more detailed version focusing on the key aspects of software development. The schedule needed several adjustments during progression, mainly due to initial lack of comprehending on scope, as well as external factors triggered by a nationwide lock-down due to the Covid-19 epidemic.

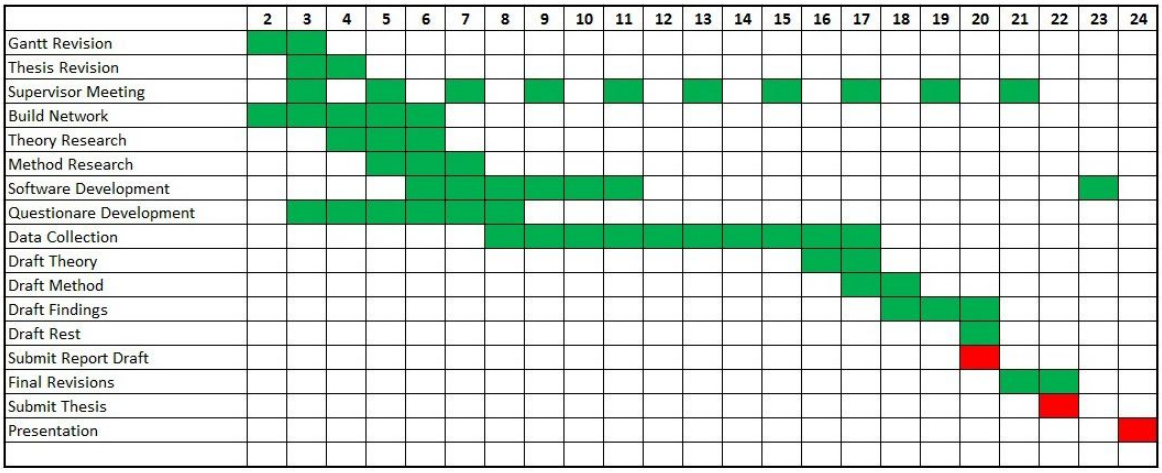


Figure 2.13: Executive Gantt Chart

Communication with supervisors were either scheduled in person or thought Zoom[58] video conferencing when needed, and the online application Trello[59] was used for additional updates and project collaboration. During this chapter, both the journey towards formulating an hypothesis and research questions, development of the prototype used to test the hypothesis, as well as the tools utilized will be described more in detail.

3.1 Preliminary Research

A general concept of this master's thesis was conceived prior to the start of the final semester, and involved the relationship and responsibilities surrounding patients and their caretakers. The notion was that current practices were not perceived as optimal, and that patient-caretaker relations could be modified in such a way as to benefit both parties. From the caretakers perspective, a notable amount of tasks performed involved normal household chores, not related to formal education taken. Patients on the other hand may need incentives or assistance to initiate and perform such

.

chores, resulting in eventually becoming more self-reliant, feeling autonomous and creating a sense of mastery within their own domain.

The assistive technology in question to be developed and tested was Augmented Reality, and researching how such technology could accommodate patients' self-reliance levels within everyday life. Literature databases were scanned to obtain more substance on AR technology within healthcare, with most cases being related to academic learning or work related utilization. Although AR often was mentioned as a potential technology for assisted living, few direct and thorough cases involving users in terms of self-reliance were identified.

3.1.1 Investigating Thesis Scope and Acquiring Key Contacts

During the start of the semester, focus was put on acquiring key contacts, and conducting brief informal dialogue with key personnel at the University of Agder, iHelse and Grimstad Kommune, relating to both AR technology and healthcare. The endeavour helped to start narrowing down thesis scope as well as acquiring information on potential user groups to target. Grimstad Kommune also provided and scheduled nurses to interview, with the aim of getting more insight into the caretaker-patient relationship.

3.1.2 Interviews with Nurses

Semi-structured one-on-one interviews for qualitative data gathering were conducted with three nurses, lasting approximately one hour each, and held at both the facilities of Grimstad Kommune as well as on university grounds. After a brief presentation of the master's thesis, giving a description of the technology and intended purpose, nurses were asked 10 questions (appendix A) regarding their occupation, general daily conduct and the potential of introducing new technologies towards their patients. Feedback during these one-on-one sessions proved valuable, both giving insight into nurses' frame of mind, potential household chores, appliances that could be targeted for AR, and general patient technological savviness.

3.1.3 Identifying Target Group and Specific Case Scenario

Several collective housing projects with mentally disabled residents were located within Grimstad municipality, either completely run by municipality caretakers, or partially through services provided to privately owned sections. Inhabitants suffered from relatively mild conditions of mental disability, thus were considered semi-independent in their daily lives.

A context of use analysis was performed at one of these facilities, where sections were owned privately complemented with public caretaker support. The inhabitants had recently experienced frequent fire alarms, followed by visits from the fire department. The reason was carelessness during cooking, where the microwave was utilized to make popcorn and other quick meals. By not comprehending the operating effect and cooking time needed, smoke eventually triggers the alarm. According to the caretakers, the events were both considered confusing and uncomfortable by the inhabitants, thus naturally unwanted. During interviews with caretakers at these locations, the decision was made to both target the patient group for the thesis, as well as utilize the specific scenario as an underlying use case. One of the cooking scenarios, making microwave popcorn, was chosen for the prototype AR application, due to the simplicity and conformity of operations, as well as potential enthusiasm for participation and consuming the end result.

3.1.4 Privacy Issues and Consent

Due to the sensitive nature of the research, involving participants with medical conditions, Norwegian Centre for Research Data[60] (NSD) was contacted at an early stage of the project. Through dialog with NSD, and taking into account participants, their guardians and relatives, a decision was made to avoid both audio and video recordings, as well as taking notes describing specific information that could be identified with individual participants. Provided such measures were taken, NSD confirmed that no application was needed to proceed with the intended research project and subsequently product testing.

A consent form (appendix B), directed towards participants and their guardians, was tailored by using a template provided on the regional committees for medical and health research ethics (REK) website[61]. The document required oral consent from all parties, with the intention of both being a precautionary measure, informing participants of their rights, as well as introducing the overall research study and description of the test involved.

3.2 Defining a Problem Space

As a deduction of the preliminary research, involving literature review and interviews with healthcare personnel, a hypothesis was formulated on the basis of the case identified. The specific circumstances surrounding the case allowed for an experiment that could measure the impact of an offered prototype solution to the problem. This chapter briefly describes both the hypothesis, the related research questions, as well as how they were intended to be measured with key performance indicators (KPIs).

3.2.1 The Hypothesis

Described more in detail earlier in this report, the case involved the occurrence of unwanted situations when housing collective inhabitants utilized their microwave to make popcorn. The reason that these situations occurred was due to a mismatch between the instructions on how the popcorn actually should be made, and the procedure performed by the users. Taken this into account, and considering the larger picture were autonomy, mastery and self-reliance may be of importance, the following hypothesis was put forth:

"Augmented Reality can be utilized as an assistive tool, to safely and correctly help users with mental disabilities perform the task of making microwave popcorn"

3.2.2 Research Questions and Key Performance Indicators
Measuring the hypothesis required questions that could guide the research and measure the statements validity. Three distinct questions were proposed as basis for testing the hypothesis:

1. **Do candidates have sufficient technical proficiency to utilize hardware platforms needed to run the application?**
2. **Do candidates comprehend the concept of Augmented Reality, and understand how to navigate the software?**
3. **Does utilization of an Augmented Reality application ensure correct tasks completion?**

First and second research questions would be measured through a quantitative interview, where candidates would evaluate their own technical expertise and understanding of the concept of Augmented Reality (yes/no). Third question would be determined through trials, where candidates would be put to the test of imitating the information given by the application, and then evaluated on the final outcome (success/failure).

3.2.3 Control Group
Due to the scope of the master's thesis and consequently the availability of candidates within the targeted group, no separate control group was set up. However, due to the specific case involved, where making microwave popcorn had resulted in frequent fire alarms by the same candidates, prior failed events were used as a measuring basis for improvement.

3.3 Researching the Design
With the hypothesis and research questions defined, focus shifted to the development of a prototype able to be tested on the target group. The method involved a human-centered design approach, focusing on understanding the users and aspects related to their interaction with the planned prototype.

3.3.1 Defining People, Activities and Context of Use
In the spirit of ISO 9241-210[62], and accounting for the references provided by the PACT model, a multiple step process was initiated, starting with brainstorming the overall concept of the patient-caretaker relationship in accordance with the thesis as shown in figure 3.1.

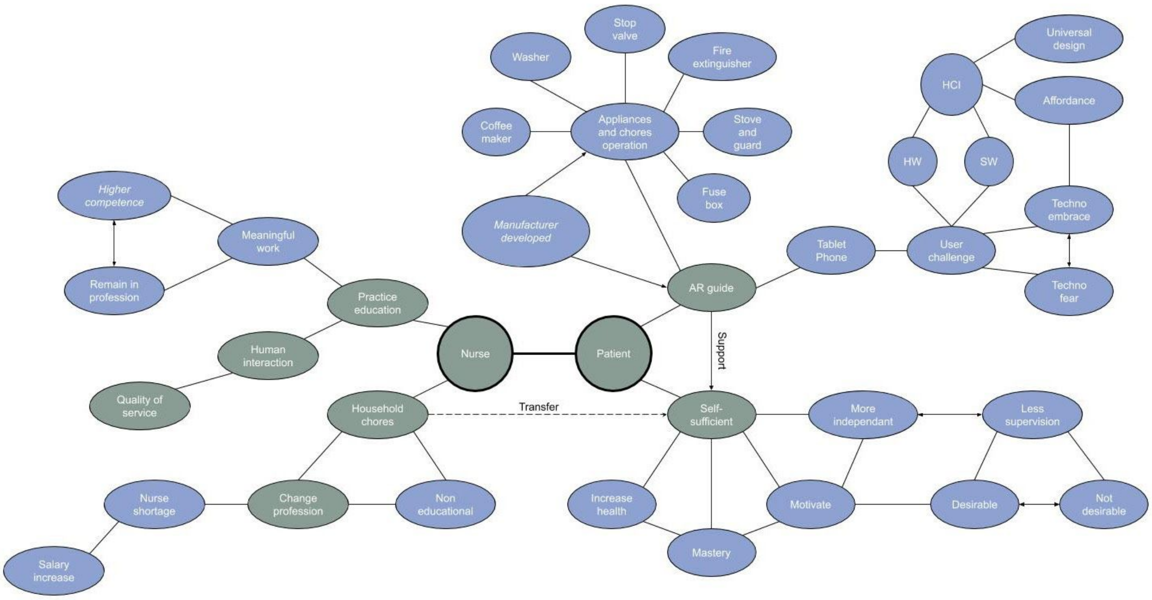


Figure 3.1: Brainstorming a Mind Map

Although the brainstorming activity, and the resulting mind-map, went far beyond the scope of the hypothesis, it gave value and insight into mapping out the stakeholders affected by developing and utilizing the proposed AR application. As figure 3.2 illustrates, the main stakeholders are the mentally disabled themselves and how the application may influence their self-reliance, sense of mastery and potentially increased well-being and quality of life as a result. The caretakers may be affected by performing less household chores as a result, having the option of focusing more on users well being rather than cleaning and preparing meals. Other main parties that may have a stake in such application utilization are the guardians, wishing for a more safe and productive environment for their child/relative. More peripheral stakeholders such as learning institutions, governmental entities and IT service providers may need to accommodate with technical equipment and training, and eventually producers of specific household appliances may want to contribute with their own more comprehensive AR product guide.

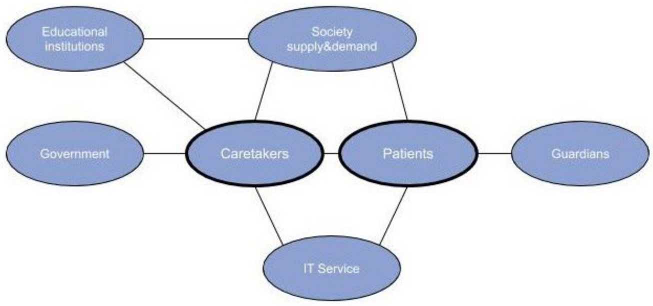


Figure 3.2: Stakeholders

Next step involved personifying the most central groups of stakeholders, by creating fictional characters representing them, to better understand their perspective and intention for promoting or using the AR application. These personas were given names, characteristics and backgrounds, tasks/goals, motivations and more as illustrated in figure 3.3, with the aim of giving insight into different real world users. The overall goal being to present subjective views of needs and requirements, giving the development process a clear goal and direction with usability in mind.

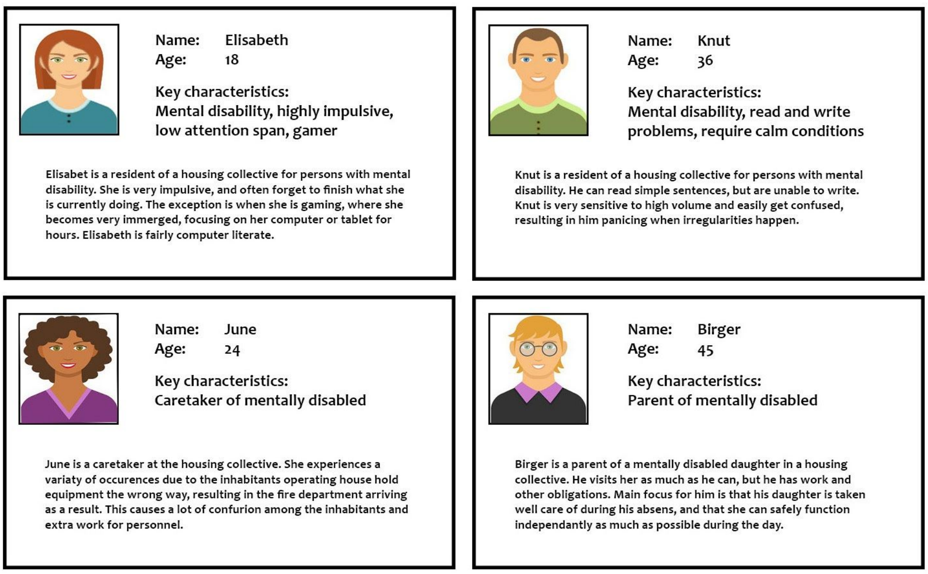


Figure 3.3: Sample of Personas

Personas were then given life through short one sentence user stories, both directly and indirectly related to intended use, represented by short descriptions of interaction or attitude towards the AR application. A wide range of stories were developed in order to get an overall view of various considerations the prototype would have to accommodate in terms of features and functionality towards the targeted user group. Figure3.4 presents samples of such stories, describing both the stakeholders state of mind, their motivation and consequent actions, revealing the intention of the application as well as the environment of intended use.

As a mentally disabled person, I want on my own terms, to be able to operate the microwave, in order to make popcorn without constant supervision, so that I feel self-reliant and like others.

As a caretaker, I want my patients to be able to learn new things, in order to develop and take responsibility, so that I can concentrate less on household chores and more on their well being.

As a parent of a mentally disabled, I want my child to be taken care of, in order for her to live as normal and independently as possible, so that I know she is both safe and happy.

Figure 3.4: Sample of User Stories

The personas with their user stories further lead to the creation of scenarios with detailed stories describing both the stakeholders and application as shown in figure 3.5. This exercise gave a better insight into personas motivation, and how users undertake the activity when using technologies such as a tablet, in order for the design to accommodate for their needs. Both a broad conceptual scenario lacking details, as well as a concrete version presenting tasks and goals, were developed to add insight from multiple perspectives and to support specific design decisions.

Conceptual

Mentally disabled people, with sufficient knowledge of smartphones/tablets as well as understanding how Augmented Reality works, will be able to get guidance from Apps on how to operate household products. Utilization of such Apps can make users operate more safely, making them become more self-reliant through eventual mastery of the appliance. More self-reliant users leads to caretakers having less household chores to perform, enabling more focus on other aspects of their job description.

Concrete

Elisabeth suddenly gets the urge to make popcorn. She knows that the process can be tricky, because she once triggered the fire alarm due to operating the microwave incorrectly. She also knows that her caretaker is currently out on assignment, and would not want her to make another scene like last time. But Elisabeth wants popcorn now, and besides, the new application she recently got, may be all the help she needs to accomplish the task. She executes the App on her tablet, points it at the microwave, and performs the step-by-step instructions given. Three minutes later, she is munching popcorn while thinking the process was a breeze. Later on, when her caretaker gets back and she gets complimented on her independence and personal development. She's on her way to becoming more grown up.

Figure 3.5: Sample of Scenarios

Next step in understanding the context of use involved creating the graphical storyboard presented in figure 3.6, utilizing the fictional personas and conceptualizing their interaction with both the system and the environment. The process involved drawing cartoon style sketches with pen and paper, encapsulating whole events as personas progressed through key segments, inspired by the user stories and scenarios previously developed. This exercise set the stage for role-play, where the personas and technology interacted both through activity, and in the context of the story in accordance with the PACT approach. The exercise of envisioning user progression gave a clearer picture on how users would perform, as well as illuminating key aspects needed within the upcoming product design.

Figure 3.6: Storyboard

Having assimilated an adequate amount of conceptual information, revealing various aspects surrounding the planned application, the process commenced with creating a high level description of how the application would be organized and operated. As figure 3.7 shows, the description highlights the activity purpose, pointing out general structure and features, as well as the end goal of the designed application. As a result, more focus was now placed on the intended design, proceeding to plan application structure and functionality, whilst considering the different aspects of usability acquired thus far.

Develop prototype application for tablets/smartphones that helps mentally disabeled with the activity of making microwave popcorn. Users are guided through a step-by-step process with AR animations, imitating the step procedure before moving onto next step. A total of five steps is needed to be replicated to complete the task. Users have the option of returning to previous steps, either to redo the step or confirm that they have performed them correctly. Upon completion all steps correctly and safely, the user is rewarded with perfectly popped popcorn.

Figure 3.7: Early sample of High Level Description

The high level description, followed up with a practical exercise performed on a privately owned microwave, eventually led to a eight step breakdown of the operation, and consequently a simple task analysis was developed. This divided nine part sequence helped to show the needed user actions in order to complete the entire process, as well as the interaction required between the user and the application keeping the PACT model in mind. Figure 3.8 illustrates an early task analysis version that eventually would undergo revisions as a result of product testing sessions later on.

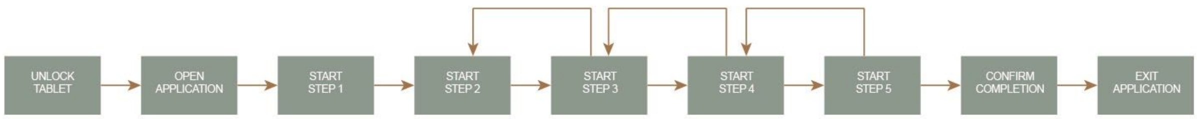


Figure 3.8: Sample of early Task-Analysis

3.3.2 UX Design Considerations

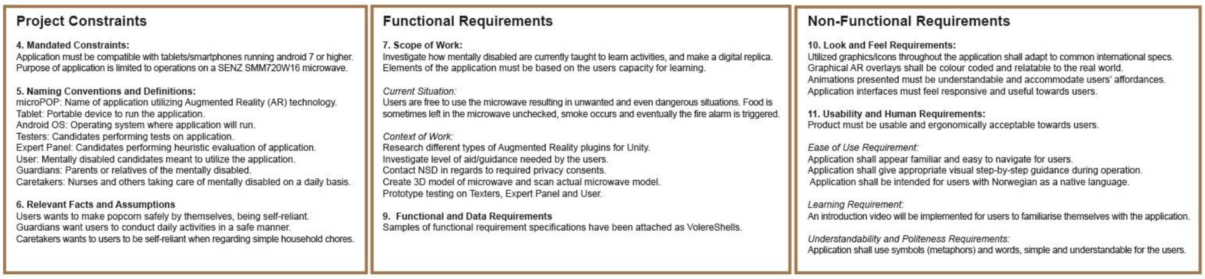
Considering the undergone process, acquiring knowledge through interviews and accounting for all aspects defined and analysed within the PACT framework, the honeycomb model[63] was utilized to understand various facets of user experience in order to initiate development.

The final prototype needed to be a useful assistive tool in such a way that it created value, and ensured that the outcome corresponded with the goal of utilization. In theory, that meant the prototype would function as a bridge between risky operations users were able to perform themselves, and a risk free operation to reach the same end goal by receiving assistance.

Considering the targeted group, the prototype needed to be highly usable and designed to accommodate the perceived level of proficiency related to words and numbering, as not to discourage utilization on a regular basis. In order to be desirable, all graphical elements and their presentation would be created to bring appeal, playing on emotions to motivate user utilization through the power of augmented reality animations and other imagery. Furthermore, these aesthetics, as well as additional aspects of the design, need to be findable and accessible, keeping in mind the intended user group that may suffer from a reduced attention span, easily becoming frustrated and distracted. Users must perceive the application as a trustful and credible tool, assisting them to reach their goal, and future upgrades may be needed to enhance the experience, increasing application value by adding new features as well as other instruction sets.

3.3.3 Specifying User Requirements for the Application

In order to summarize data within a structured framework, the Volere Requirements Specification Template was adopted[64]. The template offered a basis for specifying requirements, with sections for each type, such as specifying drivers, constraints, functional- and non-functional requirements as well as mapping other potential project issues. As figure 3.8 shows, the framework provided a systematic and detailed list of requirements, revised several times during application development, as a result of user testing and subsequently design iterations.



Project Constraints

4. Mandated Constraints:
Application must be compatible with tablets/smartphones running android 7 or higher.
Purpose of application is limited to operations on a SENZ SMM720W16 microwave.

5. Naming Conventions and Definitions:
microPOP: Name of application utilizing Augmented Reality (AR) technology.
Tablet: Portable device to run the application.
Android OS: Operating system where application will run.
Testers: Candidates performing tests on application.
Expert Panel: Candidates performing heuristic evaluation of application.
User: Mentally disabled candidates meant to utilize the application.
Guardians: Parents or relatives of the mentally disabled.
Caretakers: Nurses and others taking care of mentally disabled on a daily basis.

6. Relevant Facts and Assumptions
Users wants to make popcorn safely by themselves, being self-reliant.
Guardians want users to conduct daily activities in a safe manner.
Caretakers wants to users to be self-reliant when regarding simple household chores.

Functional Requirements

7. Scope of Work:
Investigate how mentally disabled are currently taught to learn activities, and make a digital replica.
Elements of the application must be based on the users capacity for learning.

Current Situation:
Users are free to use the microwave resulting in unwanted and even dangerous situations. Food is sometimes left in the microwave unchecked, smoke occurs and eventually the fire alarm is triggered.

Context of Work:
Research different types of Augmented Reality plugins for Unity.
Investigate level of aid/guidance needed by the users.
Contact NSD in regards to required privacy consents.
Create 3D model of microwave and scan actual microwave model.
Prototype testing on Texters, Expert Panel and User.

9. Functional and Data Requirements
Samples of functional requirement specifications have been attached as VolereShells.

Non-Functional Requirements

10. Look and Feel Requirements:
Utilized graphics/icons throughout the application shall adapt to common international specs.
Graphical AR overlays shall be colour coded and relatable to the real world.
Animations presented must be understandable and accommodate users' affordances.
Application interfaces must feel responsive and useful towards users.

11. Usability and Human Requirements:
Product must be usable and ergonomically acceptable towards users.

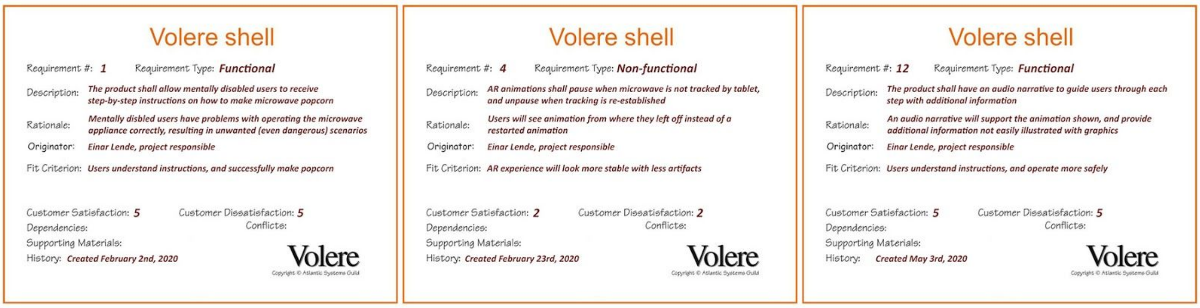
Ease of Use Requirement:
Application shall appear familiar and easy to navigate for users.
Application shall give appropriate visual step-by-step guidance during operation.
Application shall be intended for users with Norwegian as a native language.

Learning Requirement:
An introduction video will be implemented for users to familiarise themselves with the application.

Understandability and Politeness Requirements:
Application shall use symbols (metaphors) and words, simple and understandable for the users.

Figure 3.8: Part sample of User Requirements

Requirements were further broken down by using requirements shells, inspired by the original Volere shell template[64], each with their own fit criterion in order to measure if proposed solutions matched the requirements. Samples of key requirements specification are presented in figure 3.9, and the number of shells developed grew during the course of product testing, as a result of disclosed deviations, weaknesses and other critical aspects of the design.



Volere shell

Requirement #: 1 Requirement Type: Functional
Description: The product shall allow mentally disabled users to receive step-by-step instructions on how to make microwave popcorn
Rationale: Mentally disbled users have problems with operating the microwave appliance correctly, resulting in unwanted (even dangerous) scenarios
Originator: Einar Lende, project responsible
Fit Criterion: Users understand instructions, and successfully make popcorn
Customer Satisfaction: 5 Customer Dissatisfaction: 5
Dependencies: Conflicts:
Supporting Materials:
History: Created February 2nd, 2020
Volere
Copyright © Atlantic Systems Guild

Volere shell

Requirement #: 4 Requirement Type: Non-functional
Description: AR animations shall pause when microwave is not tracked by tablet, and unpause when tracking is re-established
Rationale: Users will see animation from where they left off instead of a restarted animation
Originator: Einar Lende, project responsible
Fit Criterion: AR experience will look more stable with less artifacts
Customer Satisfaction: 2 Customer Dissatisfaction: 2
Dependencies: Conflicts:
Supporting Materials:
History: Created February 23rd, 2020
Volere
Copyright © Atlantic Systems Guild

Volere shell

Requirement #: 12 Requirement Type: Functional
Description: The product shall have an audio narrative to guide users through each step with additional information
Rationale: An audio narrative will support the animation shown, and provide additional information not easily illustrated with graphics
Originator: Einar Lende, project responsible
Fit Criterion: Users understand instructions, and operate more safely
Customer Satisfaction: 5 Customer Dissatisfaction: 5
Dependencies: Conflicts:
Supporting Materials:
History: Created May 3rd, 2020
Volere
Copyright © Atlantic Systems Guild

Figure 3.9: Samples of Volere Shells[64]

Both the Requirement specification framework and corresponding detailed requirement shells became the essential framework during the design process, guiding development and maintaining focus on core elements and application purpose.

3.4 Prototype Development

Focus now shifted towards application development, and applying the knowledge gained through the different exercises of understanding both context of use and the human-centered design. This chapter breaks down the progression, from researching and evaluating potential software and hardware solutions to finalizing the prototype through stages of development.

3.4.1 Hardware and Software Utilization

Due to the probability of user testing occurring at multiple locations, where the intended appliance may be different, a decision was made to invest in a SENZ SMM720W16 microwave, purchased locally at the POWER appliance store as shown in figure 3.10. Although the choice of brand and configuration simplified the 3D modelling process due to the simplistic design, it proved to be more challenging to track within the AR application. A Samsung S5e android based tablet was chosen as the presentation medium for the AR prototype, proving to be compatible with all AR software tested during the project, and supplied with compliments of the university.

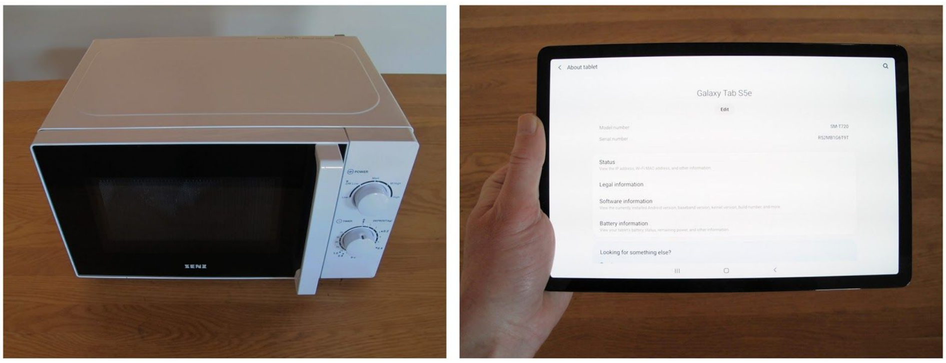


Figure 3.10: SENZ SMM720W16 Microwave and Samsung S5e Tablet

Throughout the prototype phase, Unity game engine remained the core foundation for developing software application, as well as porting the result to an android based platform. Each operational step was created as a separate scene in Unity, and a navigation system with corresponding icons ensured proper interaction throughout the application. 3D modelling of all AR elements, including needed animations, was conducted in 3D Studio Max, before importing the results as an FBX file format into Unity. 2D graphical elements such as user interface icons, application logo and tracking symbols, were edited or produced in Adobe Photoshop and Illustrator, with final material mapping of objects conducted in Substance Painter to ensure accurate placement on objects. Video segments, .

used in both the introduction and as guides in each operation step, was captured with personal equipment, and edited within Adobe Premiere, with added audio narrative created at the website animaker.com[65]. Three augmented reality plugins for Unity were tested prior to development namely EasyAR, ARCore and Vuforia, in order to evaluate the best suited solution for the task at hand.

3.4.2 Evaluating Augmented Reality Platform Providers and tracking options

Recent years have seen an increase in the amount of AR development kits suppliers, offering both standalone software and plugin features for Unity. Features for each plugin varied, as well as usability, output stability and cost for utilization. Three cost free candidates, all offering a unity plugin option were chosen as candidates, and evaluated as to their complexity and ability to meet the needs for the intended application.

As implied by name, EasyAR[66] represented the most simplistic plugin, being uncomplicated in terms of Unity implementation, development of simple AR solutions as well as porting and compatibility with most android based tablets and smartphones. However, the software simplicity and lack of strong community support, would make it harder to achieve more complex goals planned. ARCore[67] had recently become a standard plugin within Unity, and seemed to have the most potential of the three, also providing strong community support through Unity forums. There were however compatibility issues with the solution, currently limiting any developed AR application to a small number of compatible mobile units that supported the ARCore plugin through Google Play store. Eventually, the Vuforia[68] kit became the software of choice, scoring high on all core evaluated aspects, as well as offering their own product scanning software that would later prove crucial to achieve visual stability with the projected graphical elements.

During AR plugin evaluation, three different types of real-world tracking options were tested, getting a better understanding of what would be best suitable for the proposed design. Surface tracking was tested in ARCore, replicated from an online youtube video[69], where the application optically scanned and interpreted the surroundings, developing a 3D map of the area, allowing AR objects to be placed at fixed positions. Image tracking involved software recognition of specific 2D symbols, imagery or other, to trigger AR elements. An example with a triggered video on a business card was created within EasyAR, and was sufficiently stable for the intended purpose, tracked only through letters and symbols on the physical card. Object tracking eventually represented the technique of choice for the prototype, recognizing and tracking entire three dimensional objects within the real world, and easily adapted through the Vuforia software. Figure 3.11 shows both each tracking type tested as well as the three evaluated AR plugins.

Figure 3.11: Examples of Tracking Options

3.4.3 Object Scanning

Vuforia provided their own object scanner software, obtained through Google Play Store, including a printable scanning target map recognized by the software. Due to the size of the scan target, a microwave with area dimensions of 43x33cm, the target map had to be scaled up. Fortunately, the supplied file was vector-based, and with the assistance of the sign manufacturer Steinmoen AS in Grimstad, a sufficient sized scanner map was acquired.

The simplicity of the chosen microwave posed a challenge during object scanning, due to having few recognizable features that the software could identify with tracking. The solution was to add extra text and symbols to the unit, for a more precise tracking and consequently a more stable AR experience. For an optimal scan, multiple locations were tried out, both privately indoors, outdoors and finally in the university audio/video lab with professional lighting giving the best results. Vuforia claims the optimal solution is to provide the exact original CAD file of the object, resulting in the most stable AR experience. Unfortunately, such files were not obtainable for the chosen microwave, thus the object scan method was performed as shown in figure 3.12.

Figure 3.12: Object Scanning at different locations

During scanning, the tablet was moved in circles around the targeted object, covering different heights and angles until the software had sufficient tracking points of an area, and highlighted it in green. This process continued until the whole microwave was tracked sufficiently. The optimal strategy seemed to be between having too many tracking points that would overload the system, and too few that resulted in detection problems when presenting the graphical overlays. Another issue was reflections on the front glass, shown by the green tracking points in figure 3.13, which created unwanted tracking references that would not occur in other locations. The final solution was to only scan the front part of the microwave, and cover the front glass with a black matte sheet of cardboard throughout the process. The scanned object files were then uploaded to the Vuforia website[68], which converted the information into a database to be used inside Unity.

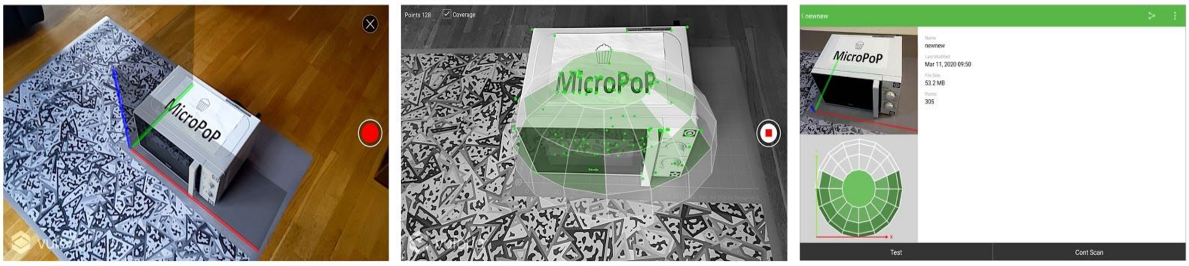


Figure 3.13: Object Scanning and Tracking Points

3.4.4 Unity Implementation

Assembling and creating the entire AR experience in Unity was made easy through pre-written scripts provided by the Vuforia SDK plugin. Setting up scenes and populating them was more or less done in the same manner as with normal game development, apart from using a custom AR camera and model target game object supplied by Vuforia. The scanned model database was uploaded to a Behaviour script within the model target game object, and developed 3D models were positioned within the assigned area on the 3D plane as shown in figure 3.14. The result being that the tablet camera would recognize the real world microwave and place the graphical overlays correspondingly. In addition, standard scripts within unity were set up to trigger both animations, as well as video and audio playback. The end result was set up to be built and ported to an android based platform.

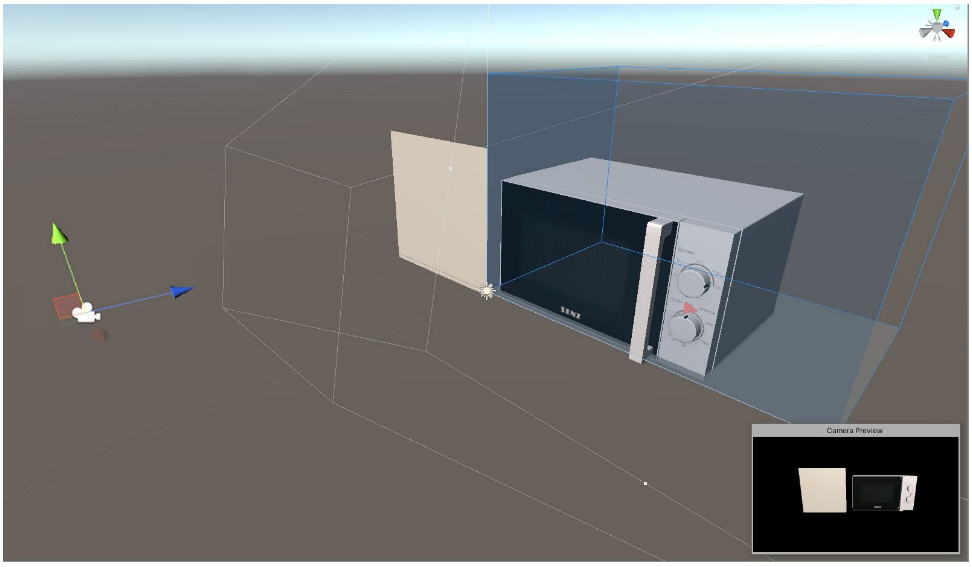


Figure 3.14: AR camera and 3D model in Unity

3.4.5 Stages of Prototype Development

Considering the nature and utilization of the application, prototype development started with brainstorming and role-play of the activity. With the actual microwave used as a prop, and a colleague performing the activity of making popcorn, the entire process was broken down into 5 main operational segments in accordance with the previously created task analysis. Later on, during an improvised low fidelity prototype test, these operational segments were presented to another colleague, which in turn was requested to maneuver a simplified paper interface as shown in figure 3.15, and imitate each segment as it was presented.

Figure 3.15: Low Fidelity Prototype Test

The exercise gave confidence as to the capability of remembering each visualized part, as well as confirming that the 5 segment breakdown had a natural division and length. As a result, the decision was made to focus on superimposed animations, bringing the whole microwave to life when looked upon with a tablet and the AR software. Photographic snapshots of the 5 steps were captured, then added graphical elements within Adobe Photoshop, and used as a guide of inspiration for further development as illustrated in figure 3.16.

Figure 3.16: Five stage operation created in Adobe Photoshop

In accordance with logged user requirements, and knowledge gained from acting out microwave sequences, the prototype software development process was initiated. First step involved 3D modelling all needed elements within 3DS Max, using techniques acquired in previous courses, and creating corresponding animations for each scene. A simple coded navigation system (appendix C) was implemented, in order for test participants to maneuver forward or backward through the different operations. In addition to the animation, a synchronized video recording of the real life event was displayed on the left side of the microwave, providing multiple options of understanding and solving each subtask. Second and third prototypes were both given major overhauls as a result of user testing, with the aim of testing out the final result on the targeted user group, thus validating the masters' thesis hypothesis. Figure 3.17 presents samples of improvements, comparing the graphical transition between early stages of prototyping and final product after iterations.

Figure 3.17: Graphical progression

3.5 Testing and Evaluation

All three prototype stages were introduced and tested with a limited group of participants throughout the development process. Each stage of testing had the goal of improving design through user feedback, and both test environment and participant backgrounds were specifically chosen to contribute to the results. This chapter will give an overall description of performed tests, the profile of test subjects, the test conduct environment as well as highlighting other aspects relating to the human-centered design process.

3.5.1 Interview Guides and Test Conduct

An interview guide, detailing all stages of conduct, were prepared prior to all official prototype tests. The contents of the guide differed depending on the specific group tested, serving both as a roadmap during sessions, and ensuring that each participant received identical presentations, test instructions as well as pre and post questionnaires. Although minor changes were made to the interview guides between groups, primarily due to product iterations, different test purposes as well as self-evaluation of interview conduct, the core mission of improving design remained the same throughout development.

During the planning phase, all hardware/software were checked, interview guide and necessary interview/observation forms structured, participants contacted and time/place negotiated, and finally a usability test plan dashboards[70] created as illustrated in figure 3.18. The general content of each test session involved a meet-and-greet, thesis and test introduction with instructions, pre test interview, product test session, post test interview and finally session wrap-up.

During testing, sessions were timed, participants conduct was observed, and notes taken to record progress and to compare results. While pre interviews had a quantitative aim, measuring participants perceived technological competence and familiarity with AR/VR, the post interviews had a qualitative approach with more in depth feedback on the test experience and potential improvements.

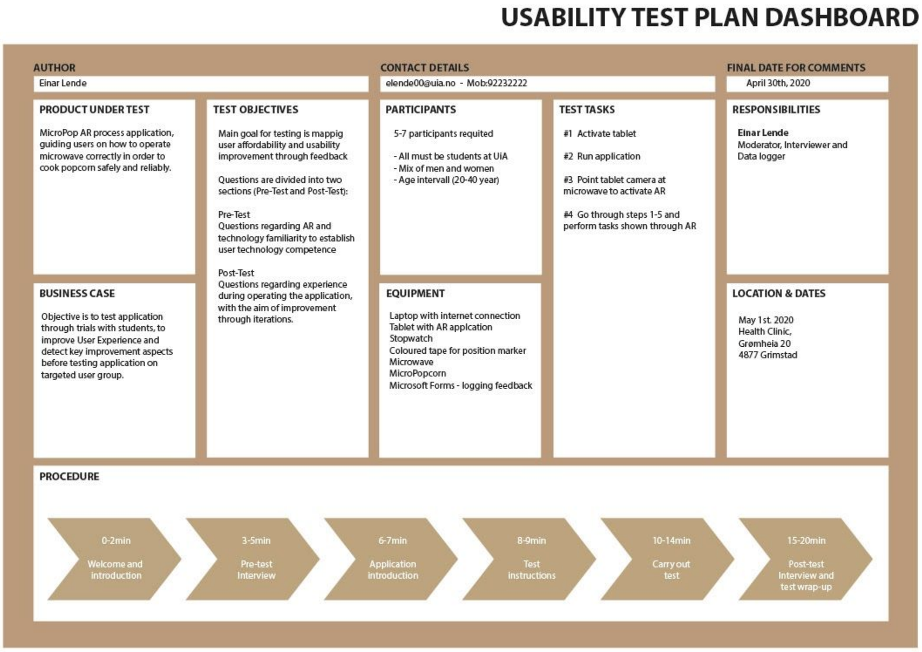


Figure 3.18: Usability Test Plan Dashboard[70]

3.5.2 Academic Test Group

First prototype underwent trials at a privately owned health treatment centre in Grimstad, where one treatment room and the reception area functioned as two separate test facilities. During this session, two different projects (AR and VR) were set up and underwent testing, sharing the group of attending test participants. This practice enabled an initial dress rehearsal, where test conductors for each project became participants for the other, resulting in valuable feedback and reflection on session conduct before testing on attendees. A total of 6 participants (age range 20-40) conducted the test, all having prior degrees of a technical nature or currently undertaking such a degree at the University of Agder. Sessions were timed and conducted according to the developed interview guide found in appendix D, and a compilation of photos taken on site are shown in figure 3.19.

Figure 3.19: Picture compilation of first prototype test facility

3.5.3 Household Test Group

Second prototype test was conducted in more related surroundings, as well as and at multiple locations, matching the normal environment for operating kitchen appliances. The four test participants (age range 40-60), composed of two separate couples, had either worked as caretakers or were parents of a child diagnosed with downs syndrome. Their knowledge on how the targeted user group would react to the technology and application, as well as ability to operate the 5 different segments, was deemed an important step in order to determine the final user experience. As with the initial student test group, the same interview guide (appendix D) was utilized, only the current participants were asked to keep their special expertise in mind when evaluating and giving feedback on the process. Figure 3.20 shows the two different setup locations for the microwave.

Figure 3.20: Picture compilation of second prototype test facilities

3.5.4 Expert Panel Test Group

In order to get a fresh perspective on design and usability, and due to their extensive knowledge within ICT and HCI, thesis supervisors were invited to form an expert panel and perform an heuristic evaluation on the final prototype. As the attendees were already familiar with the development process, the evaluation commenced after receiving a brief introduction as well as heuristic guidelines (appendix E) for evaluating the design. A total of nine heuristics, framing the multiple aspects of the AR design, developed by Endsley et al.[71] and based on Nielsen and Molich[72], were presented for the evaluation:

1. **Fit with user environment and task**
   Meaningful visualizations and metaphors within the presented physical and task environment
2. **Form communicates function**
   Virtual element form should rely on existing and familiar metaphors
3. **Minimize distraction and overload**
   Minimize accidental distraction due to movement filled and overly cluttered designs
4. **Adaptation to user position and motion**
   Useful and usable virtual elements, viewable from multiple angles, distances and while moving
5. **Alignment of physical and virtual worlds**
   Placement of virtual elements should make sense in the physical environment
6. **Fit with user's physical abilities**
   All physical interaction should be easy, and not require excess amounts of coordination
7. **Fit with user's perceptual abilities**
   Size, color, motion, distance, and resolution should be within users perceptual thresholds
8. **Accessibility of off screen objects**
   Easy to recall and locate out of view items, when they need to be manipulate
9. **Accounting for hardware capabilities**
   Application should accommodate the capabilities and limitations of intended hardware platform

The process was conducted at privately owned facilities, with one panel member physically present, and another joining in by zoom[58] to follow the procedure through a third person camera view as shown in figure 3.21. After completion, the panel were expected to initiate their own session, discussing and evaluating aspects of the application in accordance with the heuristic criteria provided, and finally submit their findings. The method helped to uncover multiple usability issues and proved a valuable addition to other user testing performed during the thesis.

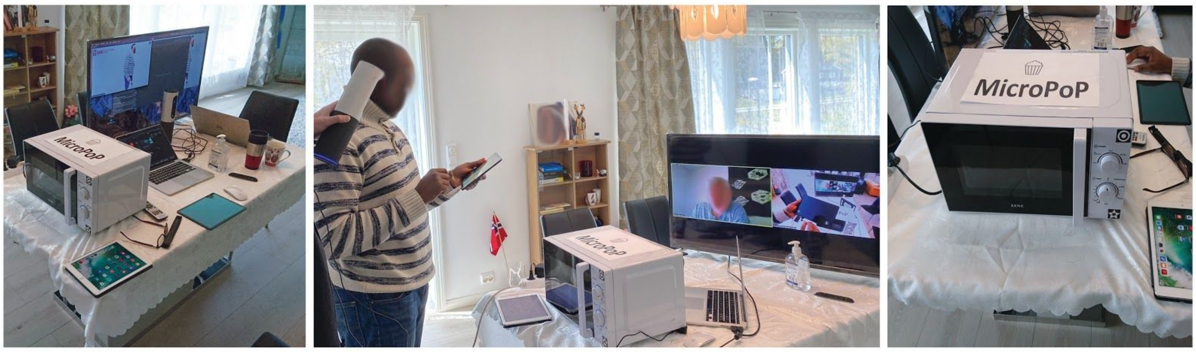


Figure 3.21: Expert Panel prototype test

3.5.5 Targeted User Group Tests

Final trials, with multiple rounds planned, were aimed towards mentally disabled participants located within Grimstad municipality. A simplified interview guide (appendix F) was constructed, in order to address both the hypothesis and corresponding research questions, as well as to get feedback for future modifications. Unfortunately, due to the national lockdown, and out of respect for participants and their guardians, these trials were not conducted within the time frame of this thesis. As a result, an attempt was made to derive a test conclusion based on performed user tests, literature review as well as feedback provided by nurses, caretakers and parents of targeted users during the project.

3.5.6 Iterations

Each round of application tests provided valuable feedback, both through observation and questionnaires, which resulted in iterations that gradually shaped the application towards the intended user group. Issues mapped, both pertaining to functional and non-functional requirements, were evaluated and given priority as to necessity and opportunity of modification, given available experience and considering project time frame. New Volere requirement shells[64] were then planned and issued to address key deviations, in order to improve on the human-centered design in accordance with ISO 9241-210[62]. Examples of such iteration will be presented and discussed briefly during the next chapter.

4 Findings and Results

The following chapter presents data accumulated throughout the thesis, covering findings through structured and unstructured preliminary interviews, observations and feedback during product testing, and finally a description of the final and revised prototype.

4.1 Preliminary Research

From a multimedia practitioner's point of view, having little prior knowledge of both healthcare services and patient needs, the preliminary research gave a broad and vital overview as a basis for the journey ahead. Early discussions with teachers and professors at UiA helped to pave the way forward by acquiring key contacts within iHealth and Grimstad Kommune.

Interviews with nurses gave a brief account of daily nurse-patient activities, relationships as well as patients technical prerequisites and desire for being self-reliant. The main focus the past decade has been to more actively involve patients in processes, by making them put in their own effort, in order to maintain individual autonomy and self-reliance. An example given was that some patients were required to find and prepare eye-dropper sets themselves before the nurse would perform the procedure, both to maintain their sense of autonomy and self-reliance.

Dialogues with Grimstad Kommune lead to focusing on specific housing collectives within the municipality, where caretakers provided both insight into daily practices as well as suggested the microwave appliance and a problem case. According to caretakers, the broad definition of "mentally disabled" covered a wide range of degrees and conditions, requiring individual approaches to learning and behavioural change. This was also the case for people with Down's Syndrome, but mild reward/punishment was often practiced as a form of learning.

One example mentioned was making soup, where participants would be handed a paper note with few letters, or only symbols depending on the severity of their condition. The main goal was not how the soup looked or tasted, but rather the step-by-step conduct to reach the final goal. They would receive feedback during progression, and in worst cases have a “time-out” or task termination if the situation got out of hand. The finished soup was a reward in itself, as more often than not the quality and taste did not affect participants' sense of achievement and desire to consume. The focus was on behavioural change, making soup safely and modifying participant conduct accordingly through multiple trials. This strategy became the basis for the developed prototype application, more or less digitizing a procedure that was already practiced.

Another example confirmed the devotion and expertise the targeted group had towards tablets and smartphones, as they had become more and more essential in their daily lives, due to ease of use. Applications utilized had less text, but rather animations, symbols and audio narratives that were easier to comprehend for the user, making them more self-motivated if they could use an App rather than a piece of paper. Gaming was one such activity, and although caretakers could not provide specific examples involving camera and graphical overlays, apps like Pokémon GO[34] and Harry Potter: Wizards Unite[35] had a familiar sound to them. Although not directly confirmed by the targeted users, there is therefore reason to believe that both their technical expertise and grasp of superimposed graphical overlays such as AR, is at a sufficient level to operate the developed prototype.

4.2 User Test Results

The intentions behind the first and second prototype trials were to both gather feedback on the design for improvement purposes, as well as getting a sense of how the targeted user group would eventually perform. The third test performed by the expert panel involved analysing specific aspects of the application rather than test performance, receiving feedback and how application elements would potentially be received by the targeted user group. All participants were only tested and interviewed once, with the results and findings presented according to the tested application version.

4.2.1 Quantitative Data

Prior to testing the application, all participants were asked to evaluate their own proficiency in regards to both the hardware and the software technology utilized (appendix D). Four questions were presented, requiring feedback on a five point Likert-type scale[73], where a higher score represented perceived high knowledge or experience. The accumulated data for both groups are presented in figure 4.1.

Participant number	01	02	03	04	05	06	Mean	07	08	09	10	Mean
Technical proficiency	4	5	3	4	5	5	4.33	3	5	2	2	3.00
Tablet/smartphone utilization	4	3	3	3	2	3	3.00	3	5	1	1	2.50
AR/VR comprehension	5	5	4	3	5	5	4.50	1	5	2	3	2.75
Utilization of AR	3	3	5	2	3	3	3.17	1	3	1	1	1.50

Group One 20-40yrs (columns 01–06)   Group Two 40-60yrs (columns 07–10)

Figure 4.1: Quantitative questionnaire - five point Likert-type scale[73]

On average, group one determined themselves to have a higher knowledge and proficiency with both hardware and software compared to group two. General technical proficiency and utilization of tablets/smartphones revealed a smaller gap than concept familiarity and prior experience with Augmented Reality between the two groups. No standard deviation could be determined with reasonable validity, due to the small amount of participants tested.

4.2.2 Test Performance and Observations

Time to completion registered for participants in both test groups got a 2:30 minute subtraction for the wait during cooking, and the second test group with prototype 2 had an additional subtraction of 1:25 minutes due to the implemented introduction video at startup. The results of all 10 participants are presented in figure 4.2. As the table shows, the first test group resulted in an average time of 2:07 minutes, while the second test group delivered a 2:53 minutes average.

Participant	Time	Result	
01	2:56	Success	Average Time 2:07
02	1:46	Success	
03	1:40	Failure	
04	1:57	Success	
05	2:00	Success	
06	2:24	Success	
07	2:56	Success	Average Time 2:53
08	2:45	Success	
09	2:50	Success	
10	3:01	Success	

Group One 20-40yrs; Group Two 40-60yrs

Figure 4.2: Prototype test time performance

Out of all test subjects, with 6 participants testing prototype 1 and 4 participants testing prototype 2, one critical error that led to overall task failure was registered. The reason was a functional weakness within the developed software design in prototype 1, where a registered double tap on the tablet made the software skip over step 2 where wattage (power) were meant to be set. The result was unpopped popcorn within the registered time frame of 2:30 minutes in step 3. A second double tap was registered by another participant, but eventually deemed non-critical as the participant made corrections by going back a step, and eventually finishing the task successfully. Both double tap occurrences happened with prototype 1, and were attended to by performing an iteration on the software. An implementation of a one second delay before enabling icon interaction on each step solved this issue (appendix C), thus there were no similar occurrences during prototype

2 testing. A second non-critical error was identified, where a participant set the time needed closer to 3 minutes

than 2:30. The occurrence did not measurably affect the task outcome, but a graphical iteration was made on the app to ensure that the expected time of 2:30 minutes were augmented more clearly and shown more within the field of view. A similar adjustment was made in regards to wattage in step 2, as shown by figure 3.16 in chapter 3.

A common theme for nearly all participants were various degrees of impatience, often wanting to perform the task before watching the entire animation play out, and even nearly advancing further than the current step suggested. This urge was more frequent for test group 2, who generally looked more confused and less calm during conduct than their counterparts.

General AR detection issues were registered with both groups, but were more frequent during the second test group, where private kitchen layouts created issues due to both lighting and participant positioning. Both low light as well as bright light which created unwanted reflections on the appliance, posed challenges for the software, and smaller kitchens limited the needed distance between the microwave and the tablet to operate properly.

4.2.3 Qualitative Data

The post questionnaire (appendix C) was tailored to give both clarification to observed test conduct, as well as to receive feedback on potential design improvements for the application. Apart from the double tapping occurrence and time selection issue already observed, the overall consensus was that the application could have potential benefits towards the targeted group.

As for the test participants themselves, the procedure of making popcorn was not unfamiliar, thus focusing solely on instructions, rather than just making popcorn, created a bit of a challenge. A common reply from group one was that they needed more time to familiarize themselves with the activity of using the application, and that a second or third time would definitely improve their performance. The same argument resonated with group two, even though participants here were presented with the instruction intro before executing the task steps.

When asked what part of the application feature (video or 3D animation) they primarily focused on during the step by step procedure, all but one participant replied the 3D animation. The "odd man out" replied that both features were equally focused on. The five step procedure as a whole were also reviewed and commented on by the participants, and both caretakers and parents in group two drew comparisons with their own prior experience and practice with mentally disabled patients. The number of steps seemed to be within reason, and the video/animations easy to understand. But using both a video and an animation showing the approximate same thing, could result in confusion depending on the condition severity for each individual user. Another potential aid or source of confusion could be the audio narrative, especially when combined with the double video and animation features, that all in all could lead to information overload for some individuals.

All participants would consider using similar AR guidance personally, for other more complicated and unfamiliar tasks if such solutions were available, providing sufficient stability and consistency of the AR app during operation. The only other potential drawback given by a participant was the need to hold the tablet, leaving only one free hand for operation, which could become a problem in certain circumstances. It was important that any AR application did not complicate matters more than their aim to function as an aid.

4.3 Expert Panel Comments

The expert panel gave clear and precise feedback in accordance with the heuristic guidelines provided prior to testing. Each Heuristic was addressed, and additional comments were provided on the overall look and feel of the application experience, both confirming comments already acquired during user testing, and highlighting new aspects of importance for further iterations and testing.

According to the expert panel, visualization and metaphors would match users expectations, and both cognitive and physical affordances were easy to percieve. The panel too raised concerns regarding having both video and animation, claiming that the combo could result in information overload for users that are already mentally challenged. Audio and graphical improvements were also suggested, in order to reduce potential confusion, as well as questions regarding how such experience would be perceived on a smaller sized smartphone were asked. Finally, possible issues with positioning were addressed, where users could potentially miss vital information if they stood too close, or lose the AR overlays if standing too far away from the microwave.

4.4 The Final Prototype

What initially started as an idea of developing virtual step-by-step instruction manuals on how to accomplish specific tasks, eventually became a fully functional AR application aimed towards the mentally disabled. Both preliminary research and various progression stages of the human-centered design process shaped the final design towards the targeted user group. User testing, as well as expert panel evaluation helped to identify and address functional and non-functional deviations, gradually improving the design integrity. The final application prototype, as presented with screenshots in figure 4.2, gives necessary guidelines on how to make popcorn safely and reliably in a microwave oven setting. The intro screen welcomes users by offering a video walkthrough on how to properly navigate the application. Users then commence with the five separate steps of conduct, eventually reaching the accomplishment screen and exit the application.

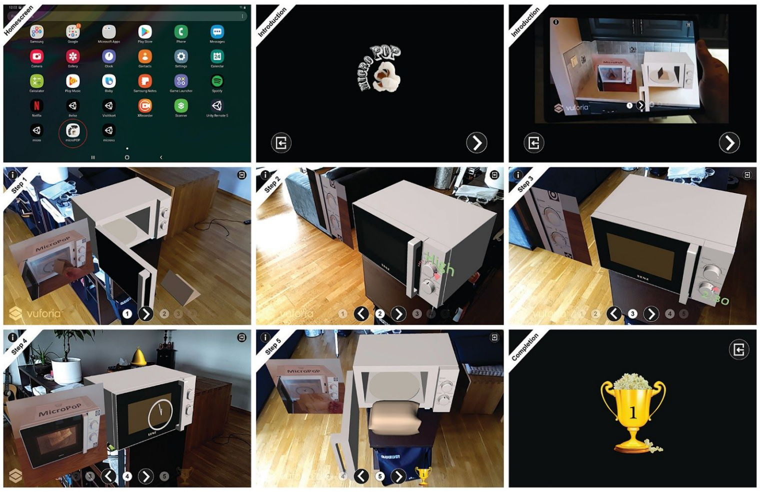


Figure 4.3: Screenshots of scenes from the final prototype

5 Discussion

This chapter discusses the project findings, and how results measure up to the hypothesis, as well as prior research within the field of AR technology towards patient healthcare. As the human-centered approach represents a central part of project methodology, both current design as well as the potential for future research and development will be addressed.

5.1 Litterature Conformity and Research Comparison

General consensus found during research involved conforming to the model of gradual behavioural change, building on drawn paper principals and presenting a digital alternative through the usage augmented reality. As highlighted earlier, the ZPD often uses the word and symbol scaffolding to describe guidance needed in order to progress. Scaffolding is a real world assistive technology, meant to support various forms of construction. The developed application and supported hardware is meant to function as ATC for users in much the same way, gradually shaping their conduct towards a more safer and reliable outcome through behaviourism.

Both intrinsic and extrinsic motivation have a chance of coexisting here, where the step-by-step tasks are logarithmic in nature, and the aim is to actually discourage creativity. Users are themselves motivated by the desire of popcorn, and may percieve to have more autonomy by having the option of utilizing the application on a regular basis, eventually mastering the entire process, creating a sense of community belonging as a result. Simultaneously, both positive and negative reinforcement is potentially received from the application and the end result itself, always aiming for a perfect outcome. As it stands, the application needs to offer more feedback on a step-by-step basis to better serve the reinforcement strategy, and further research and development will be needed to accomplish this endeavor. Finally, considering individual sensory preferences as presented by the VARK model, design needs to be tailored in such a way as to benefit the individual experience, not bombarding users with guidance potentially resulting in confusion or information overload.

When comparing current thesis with the AR usability research conducted by the Technical University of Munich[51], there are both similarities and distinct differences in regards to test group demographics, methodology and prototype design. Although both projects deal with cognitively impared candidates, both the age group, specific medical conditions and affordances for operating digital equipment are different.

Both research projects had a user-centered focus during prototype development, but the test equipment utilized were different. Rohrbach et al. developed a more extensive design for the Microsoft Hololens, rather than opting for a potentially more familiar tablet or smartphone. Feedback given on the Hololens suggests that it may be too heavy and uncomfortable as well as

.

unfamiliar, but the head gear did allow for both hands to operate tasks at all times, as opposed to utilizing a tablet.

The approach of utilizing AR to provide virtual instructions is also a common theme, but Rohrbach et al. chose a graphical presentation further to the left on Milgram's Reality-Virtuality continuum[26]. Their approach centered around freely floating animations, detached from the actual appliance, while this thesis offered a superimposed alternative. Both approaches have their advantages and disadvantages in terms of testing and eventual implementation. Separate shown animations may be more applicable towards other appliance brands with the same operation outline, but can also result in confusion when procedure is to be replicated on the actual appliance as stated in their report. The superimposed AR solution (augmented virtuality) provided in this thesis may prove to better relate towards cognitive impared users, but both the development process may be more demanding, as well as the design having a narrower field of utilization.

Performance during trials between the two projects cannot be subjected to direct comparison as such, but there are similarities as to participant behaviour and performance, as well as feedback received after testing. A common denominator for both research projects were participant confusion and impatience during test conduct, as well as the feedback given on sensory preferences during post interviews.

5.2 Evaluating Human-centered Design Process

Personal recommendations for supervisors involved in the thesis, were based on their expertise within interaction design and ICT technology implementation towards healthcare, which proved valuable during project progression and eventual expert testing.

The UX design process eventually became more comprehensive than initially anticipated, due to limited user group access, thus more focus was put on refining the prototype design. This gave an opportunity to better understand interaction design in context of the thesis use case, as well as the contribution value such processes can provide when developing prototypes for scientific research. This may be especially relevant when test subjects suffer from various conditions and degrees of cognitive impairment, where a profiled user-centered group design could affect the test outcome and consequently the overall conclusion.

The methodology provided within the UX design framework greatly helped to plan and structure the entire development process, as well as to highlight important aspects to consider during progression. Guidelines provided detailed instructions as to how to bring conceptualized ideas from paper form to eventual fully operational applications through various forms of prototype testing.

5.3 Findings in Relation to the Hypothesis

Validating the hypothesis without access to the actual user group, nor the ability to perform user tests on an acceptable number of test participants, made for a less than desired project outcome. However, based on preliminary research, tests performed, and the quantitative and qualitative feedback from participants, indicators point towards conclusions that can be taken into account pending further research on the topic.

First research question addressed whether or not candidates in the targeted user group had sufficient technical proficiency to utilize hardware platforms and eventually run the developed application. Preliminary interviews involving caretakers suggest that digital equipment such as smartphones and tablets are frequently used, due to ease of accessing software with information and navigation often presented with symbols rather than text. Many apps seem to conform with the affordances of the target group, to the point that tablets and smartphones have become indispensable in their daily lives. Based on the frequent utilization described by caretakers, data suggest that the target group possess sufficient technical knowledge to operate the developed application.

Second research question involved candidates' ability to comprehend and utilize the AR technology. According to the caretakers and parents of mentally disabled, gaming was a primary leisure activity for some, but they had little knowledge on what type of games that were played. However, mentioned games like Pokemon GO[34] and Harry Potter:Wizards Unite[35] sounded familiar, suggesting that candidates may have prior experience with applications projecting graphical overlays through real world video footage. Assumed knowledge level should therefore be sufficient for utilizing the application, especially considering that trials performed showed even test subjects with little knowledge of AR quickly adjusting to the software technology.

Determining whether or not the application results in correct task completion, asked by the third research question, requires actual prototype trials on the targeted user group. Trials conducted suggest that both candidates with a high and low level of technical expertise, aging from twenty to sixty years of age, are apt to follow instructions provided by the tested application on first tryout. A total of 9 out of 10 tests were conducted successfully, with the failed cause determined to be an error of the application, and later corrected through prototype revision. Age did seem to affect the required time to complete the task, as group two on average required 36 percent longer than group one. Feedback received suggests that performance would improve for all candidates if put through a second and third test, making them more familiar with the application framework. Additional revisions to the prototype, taking individual capabilities and affordances into account, would make the design ever more usable. Nevertheless, without direct testing, and only speculative feedback as to the benefits of the application towards the targeted group, the third research question remains unanswered.

Based on current findings, addressing the research questions pertaining to the proposed hypothesis, thesis validation remains inconclusive. However, data collected does suggest that AR technology has benefits as an assistive technology towards daily activities, provided the design is proven usable by the individual. Further research is therefore recommended, in order to determine both the validity of the hypothesis, as well as the extent of support AR technology can provide towards the mentally disabled.

5.4 Forecasting Future Potential

Reviewing the current research literature available on AR implementation towards the cognitive impared is for the time being a scarce commodity, and should be investigated further as both software and hardware platforms are evolving rapidly. Combining AR features with sensors and artificial intelligence algorithms will allow the software to give feedback on user actions. Better optical hardware, CPU processing power as well as optimized software detection algorithms will make for a more realistic and stable experience. User data collection and pattern analysis may set the stage for tailored content to better meet individual needs and expectations.

At a certain point, the practicality of making AR solutions toward appliances needs to be addressed, as well as a strategy for optimizing development of such support. It is one thing to develop a specific AR solution for one person, and another when dealing with an institution or a group of users that operate the exact same household appliance. Eventually, companies that produce appliances towards world market demand, would be best equipped for the task, already possessing both the digital design and expert knowledge on product functions.

As for the current developed prototype, future progress should involve evaluation and revision according to heuristic findings addressed by the expert panel before tests on the targeted user group commences. As practised by Rohrbach et al.[52], the test should be performed several times in order to measure any improvement in conduct by each participant. All in all, as the hypothesis is not currently validated, further research is recommended to determine if AR support can make a difference as an assistive technology to support activities of daily living for the mentally disabled.

6 Conclusion

This masters' thesis has presented the research, workflow and findings relating to development of an Augmented Reality application, meant as support for the mentally disabled. Preliminary research gave both an overview of the potential for the technology towards healthcare, as well as confirming relevant learning theory and application design strategy.

During the prototype development process, UX design became a central theme, shaping the application to better accommodate the needs of the intended user group. The human-centered design process helped to get into the mindset of potential stakeholders, giving insight on the context of use and structure requirements accordingly. Preliminary prototype testing and expert panel feedback resulted in system iterations that improved the overall design. Furthermore, quantitative and qualitative feedback during these tests strengthened the notion that an AR guidance could present benefits as an assistive technology towards performing daily activities.

The final leg of the masters' program proved to be a formidable challenge, but nevertheless an invaluable experience that resulted in knowledge gained on both AR technology, as well as the implementation potential within the healthcare sector. Although the final stretch of research involving prototype testing towards the targeted user group proved impractical due to a national and regional lockdown, preliminary findings showed promising potential requiring further investigation.

As a result, the hypothesis set forth by this thesis, involving utilization of AR technology as an assistive tool to guide the mental disabled, remains unvalidated for the time being. Further research on the topic is encouraged to determine the extent of which AR can provide practical guidance toward the intended user group. Multiple user trials is also recommended, in order to measure, increased competence and potential behavioural change among the participants.

7 References

[1] Augmented Reality in Rehabilitation, no author, http://www.therapylens.com/

[2] Smith M.K. (1999), Learning theory , the encyclopedia of informal education. http://www.infed.org/biblio/b-learn.htm

[3] W-H. Wu H-C. Hsiao P-L. Wu C-H. Lin S-H. Huang (2012), Investigating the learning-theory foundations of game-based learning: a meta-analysis, Journal of computer assisted learning, Volume 28, Issue 3, pp.265-279

[4] Grippin P. & Peters S. (1983), Learning Theory and LearningOutcomes: The Connection , University Press of America,Inc., Lanham, MD

[5] Staddon JE, Cerutti DT (2003), Operant conditioning. Annu Rev Psychol., https://pubmed.ncbi.nlm.nih.gov/12415075/

[6] David C. Leonard (2002), Learning Theories: A to Z , Greenwood Publishing Group, Unites States of America. PP.16

[7] Eikeseth & Svartdal (2010), Anvendt atferdsanalyse - Teori og praksis, Gyldendal Akademisk, Chapter 14, pp. 316-336

[8] Vygotsky, L. S. (1978), Mind in society, Cambridge, MA: Harvard University Press

[9] G. Wells (1999), The zone of proximal development and its implications for learning and teaching, Dialogic inquiry: Towards a sociocultural practice and theory of education, pp. 313–334,

[10] R. Tharp and R. Gallimore(1991), A theory of teaching as assisted performance, Learning to think, vol. 2, pp. 42

[11] Fleming, N.D. & Mills, C (1992), Not Another Inventory, Rather a Catalyst for Reflection. To Improve the Academy, 11, pp. 137-155.

[12] T. C. . S.-Y. Yoon, “Augmented reality, virtual reality and their effect on learning style in the creative design process.” https://files.eric.ed.gov/fulltext/EJ1171588.pdf

[13] Carol Sansone, Judith M. Harackiewicz (2000), Intrinsic and Extrinsic Motivation: The Search for Optimal Motivation and Performance, Academic Press, USA, pp. XVII

[14] Deci, E. L. & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. Psychological Inquiry 11 (4), 227-268

[15] Harry F. Harlow, Margaret Kuenne Harlow, and Donald R. Meyer, 1950, Learning Motivated by a Manipulation Drive, Journal of Experimental Psychology 40, p. 231.

[16] Dörnyei, Z. & E. Ushioda (2013). Teaching and Researching: Motivation. 2nd ed. Harlow: Longman.

[17] Ed. by R. M. Ryan (2012), Motivation, Personality, and Development Within Embedded Social Contexts: An Overview of Self-Determination Theory, The Oxford Handbook of Human Motivation, Oxford University Press. pp. 8, 85-107

[18] Ryan, R. M., & Deci, E. L. (2009). Promoting self-determined school engagement: Motivation, learning, and well-being. In K. R. Wenzel & A. Wigfield (Eds.), Educational psychology handbook series. Handbook of motivation at school (p. 171–195). Routledge/Taylor & Francis Group.

[19] J. Bentham (1825), The Rationale of Reward, Robert Heward, London

[20] Daniel H. Pink (2009), Drive: The Surprising Truth About What Motivates Us, Riverhead Books, New York,pp.30-43

[21] Carl Mellström and Magnus Johannesson (2008), “Crowding Out in Blood Donation: Was Titmuss Right?” Journal of the European Economic Association 6, no. 4, pp. 45-63.

[22] Deci, E. L., & Ryan, R. M. (1985), Intrinsic motivation and self-determination in human behavior, New York: Plenum.
[23] Lepper, M. K., Greene, D., & Nisbett, R. (1973). Undermining children's intrinsic interest with extrinsic reward: A test of the "overjustification" hypothesis. Journal of Personality and Social Psychology, 28, pp. 129–137.
[24] Cambridge Dictionary website, https://dictionary.cambridge.org/dictionary/english/virtual-reality
[25] Merriam-webster Dictionary website, https://www.merriam-webster.com/dictionary/virtual%20reality
[26] Milgram, Paul; H. Takemura; A. Utsumi; F. Kishino (1994), Augmented Reality: A class of displays on the reality-virtuality continuum" (PDF). Proceedings of Telemanipulator and Telepresence Technologies. pp. 2351–34
[27] S. M. LaValle (2019), Virtual Reality, University of Oulu, http://vr.cs.uiuc.edu/, pp.25-29

[28] Whatever Happened to Virtual Reality? (2004), no author, NASAexplores https://www.nasa.gov/audience/forstudents/9-12/features/F_What_Happened_to_Virtual_Reality_9-12.html

[29] Sparto, P.J., Whitney, S.L., Hodges, L.F. et al. (2004), Simulator sickness when performing gaze shifts within a wide field of view optic flow environment: preliminary evidence for using virtual reality in vestibular rehabilitation. J NeuroEngineering Rehabil 1, pp.14
[30] Oculus VR official website, https://www.oculus.com/
[31] Steuer, J. (1992), Defining Virtual Reality: Dimensions Determining Telepresence. Journal of Communication, pp, 73–93
[32] R.T. Azuma (1997), A survey of augmented reality, Presence: Teleoperators and Virtual Environments, pp. 355–385,.
[33] Lamb, P. (2003). ARToolKit. http://www.hitl.washington.edu/artoolkit/
[34] Pokémon GO official website, https://www.pokemongo.com/en-us/
[35] Harry Potter: Wizards Unite official webpage, https://www.harrypotterwizardsunite.com/
[36] Microsoft official webpage, https://www.microsoft.com/en-us/hololens
[37] Chen, Huixiang & Dai, Yuting & Meng, Hao & Chen, Yilun & Li, Tao (2018), Understanding the Characteristics of Mobile Augmented Reality Applications, pp. 128-138.
[38] Kruijff, Ernst & Swan, J. & Feiner, Steven (2010), Perceptual issues in augmented reality revisited. 9th IEEE International Symposium on Mixed and Augmented Reality 2010: Science and Technology, ISMAR 2010
[39] Kapp, E. (1877), Grundlinien einer Philosophie der Technik" (Elements of a Philosophy of Technology). Braunmschwieg, Germany: Westermann
[40] McLuhan, M. (1964), Understanding media: The extensions of man. New York: McGraw-Hill.
[41] Best, Catherine & O'Neill, Brian & Gillespie, Alex. (2014), Assistive Technology for Cognition: An Updated Review,
[42] Weinstein, Aviv & Lejoyeux, Michel. (2010). Internet Addiction or Excessive Internet Use. The American journal of drug and alcohol abuse. 36. 277-83.
[43] Syed, Liyakathunisa & Jabeen, Saima & Manimala, S. & Alsaeedi, Abdullah (2019), Smart healthcare framework for ambient assisted living using IoMT and big data analytics techniques. Future Generation Computer Systems
[44] Eleonora Bottani & Giuseppe Vignali (2019), Augmented reality technology in the manufacturing industry: A review of the last decade, IISE Transactions
[45] Ting-Wen Chang Ronghuai Huang Kinshuk (2018), Authentic Learning Through Advances in Technologies, Springer Nature Singapore Pte Ltd. pp.197-199
[46] How Volkswagen is Developing the Car of the Future Virtually, 2017, Volkswagen https://www.volkswagenag.com/en/news/stories/2017/03/how-volkswagen-is-developing-the-car-of-the-future-virtually.html#
[47] Queiro, Silva Alvarelhão, Rocha, Teixeira (2013), Usability, accessibility and ambient-assisted living: a systematic literature review, Springer-Verlag Berlin Heidelberg

[48] Pieper, M., Antona, M., Cortes, U. (2011), Introduction to the Special Theme. Ambient Assistive Living. ERCIM News, 87, pp. 18-19

[49] Pavolini, E., & Ranci, C. (2008), Restructuring the welfare state: Reforms in long-term care in Western European countries. Journal of European Social Policy, 18, pp.246.

[50] Williams, B.C., Fries, B.E., Foley, W.J., Schneider, D., & Gavazzi, M. (1994), Activities of daily living and costs in nursing homes. Health Care Financing Review, 15, pp.117–135.

[51] Rohrbach, Philipp Gulde, Armstrong1, Hartig , Abdelrazeq, StSchröder, Neuse, Grimmer, Diehl-Schmid, Hermsdörfer (2019), An augmented reality approach for ADL support in Alzheimer's disease: a crossover trial, Journal of NeuroEngineering and Rehabilitation

[52] Meiland F, Innes A, Mountain G, Robinson L, van der Roest H, García-Casal JA, et al (2017), Technologies to support community-dwelling persons with dementia: a position paper on issues regarding development, usability, effectiveness and cost-effectiveness, deployment, and ethics. JMIR Rehabil Assist Techno

[53] LoPresti, E.F., Mihailidis, A., & Kirsch, N. (2004), Assistive technology for cognitive rehabilitation: State of the art. Neuropsychological Rehabilitation, 14, pp. 5–39

[54] de Joode, E., van Heugten, C., Verhey, F., & van Boxtel, M. (2010), Efficacy and usability of assistive technology for patients with cognitive deficits: A systematic review. Clinical Rehabilitation, 24, pp. 701–714.

[55] Esteban Guerrero, Ming-Hsin Lu , Hsiu-Ping Yueh, Helena Lindgren (2019), Designing and evaluating an intelligent augmented reality system for assisting older adults' medication management, Elsevier

[56] Livingston, M.A., Zanbaka, C., Swan, J.E. and Smallman, H.S. (2005), Objective measures for the effectiveness of augmented reality, in Proceedings of the Virtual Reality Conference, IEEE, US, pp. 287–288.

[57] Research Methodology website, https://research-methodology.net/research-methodology/research-approach/

[58] Zoom website, https://zoom.us/

[59] Trello website, https://trello.com/

[60] Norwegian Centre for Research Data, https://nsd.no/personvernombud/en/notify/

[61] Regionale komiteer for medisinsk og helsefaglig forskningsetikk, https://rekportalen.no/#home/informasjonsskriv

[62] International Organization for Standardization. "ISO 9241-210:2019" https://www.iso.org/standard/52075.html.

[63] Peter Morville (2004), User Experience Design, Semantic Studios, https://semanticstudios.com/user_experience_design/

[64] Volere Requirement Resources, https://www.volere.org/templates/volere-requirements-specification-template/

[65] Animaker website, https://www.animaker.com/voice

[66] Easy AR website, https://easyar.com/

[67] ARCore website, https://developers.google.com/ar

[68] Vuforia website, https://www.ptc.com/en/products/augmented-reality

[69] Zenva academy, Complete Course - Learn Unity's AR Foundation, https://www.youtube.com/watch?v=FGh7f-PaGQc

[70] D. D. Travis, "The 1-page usability test plan.", https://www.userfocus.co.uk/articles/ usability_test_plan_dashboard.html.

[71] Tristan C. Endsley, Kelly A. Sprehn, Ryan M. Brill, Kimberly J. Ryan, Emily C. Vincent, James M. Martin Draper (2017), Augmented Reality Design Heuristics: Designing for Dynamic Interactions, Cambridge, MA

[72] Jennifer Preece, Helen Sharp, Yvonne Rogers (2015), Interaction Design: beyond human–computer interaction, 4th edition, John Wiley & Sons Ltd, United Kingdom, Ch.15

[73] Likert, R. (1932), A technique for the measurement of attitudes. Archives of Psychology, 22(140), pp. 1-55.

8 Appendices

Åpen Spørreundersøkelse - Pleiere

1. Beskriv kort en vanling visitt hos pasienten:
- Hvor lenge varer den
- Hva slags arbeid utføres
- Hvor mye interaksjon med pasienten
- Hvilke ferdigheter anvendes (personlige/akademiske)

2. Beskriv forholdet med pasienten:
- Nært forhold eller mer formelt
- Mange forskjellige pleiere per pasient eller få
- Samme pasient i lengre tid eller rotasjon

3. Arbeidsoppgaver rettet mot utdannelse eller daglige gjøremål:
- Hva defineres som hovedmengde av arbeid
- Hva er akademisk relatert og hva er ikke

4. Hva slags type arbeid motiverer deg som pleier:
- Akademisk relatert arbeide
- Daglige gjøremål
- Annet

5. Vurderinger rundt fremtidig arbeidssituasjon
- Hvor lenge ser du seg selv som pleier i nåværende arbeidssituasjon
- Føler du selv at det er mye gjennomtrekk av medarbeidere i samme yrke
- Hva vil påvirke din arbeidssituasjon til å vare lenge/kortere

6. I din oppfatning, beskriv pasienters ønske/behov for å utføre daglige gjøremål selv:
- Ikke interessert
- Kan utføre, men det blir gjort uansett
- ønsker, men trenger assistanse
- Annet

7. Hva er ditt inntrykk av pasienters holdning/kunnskap rundt moderne data/elektronikk:
- Benyttelse av moderne telefoner og tablet
- Kunnskap om Apper og internet
- Generelt interessert i ny teknologi

8. Din mening om teknologi som Augmented Reality for å aktivisere/motivere pasienter:
- Vil slik teknologi omfavnes av pasienter
- Finnes det et potensial for læring/mestring/motivasjon
- Potensial for mer selvstendighet og forbedret helse

9. Hvilke operasjoner/gjøremål kan være et startspunkt for å introdusere Augmented Reality:
- husholdnings apparat
- Navigering i hus
- Annet

10. Hvilke fordeler/ulemper ser du for deg at en implementasjon av Augmented Reality kan ha:

Universitetet i Agder

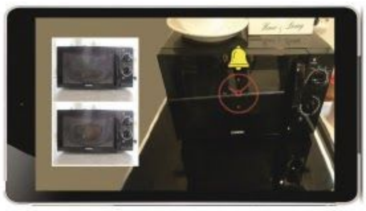
INFOSKRIV: FORESPØRSEL OM DELTAKELSE I FORSKNINGSPROSJEKTET

BRUK AV AUGMENTED REALITY(AR) APP SOM BRUKERVEILEDNIG

Dette er en forespørsel til deg/foresatte om å delta i et forskningsprosjekt for å teste AR applikasjon gjennom nettbrett, med mål å forske på om applikasjoner med enkle steg-for-steg instruksjoner kan hjelpe brukere å håndtere husholdningsapparater på en mer effektiv og sikker måte. Kandidat er utvalgt grunnet deres helse og bosituasjon, og har blitt nevnt som potensielle kandidat gjennom dialog med ansatte i Grimstad Kommune.

HVA INNEBÆRER PROSJEKTET?

Det vil først foretas et intervju med deltakere for å forstå deres tekniske kunnskaper rundt å bruke nettbrett og forståelse av hvordan Augmented Reality fungerer. Deltakene blir så presentert med en App på ett nettbrett. Når nettbrettet holdes foran en husholdningsmaskin vil animasjoner og instruksjoner bli vist på skjerm. Deltakere får tildelt en uferdig pose med micropopcorn, og skal gjennom instruksjoner på nettbrett oppnå ferdig spiselige popcorn ved bruk av en mikrobølgeovn.

Prosjekt omhandler 2-3 testrunder (ca. 10-15min hver) i løpet av 1-2 måneder for at utvikler skal ha mulighet til å forbedre instruksjonene og lage en mest mulig fungerende løsning. Deltakere vil ikke bli filmet og det vil ikke samles inn personlige data om deltagere. Det vil kun bli foretatt observasjoner rundt forståelse og utførelse av oppgave og skriftlige notater fra intervju.

MUNTLIG SAMTYKKE

Det ønskes et muntlig samtykke fra kandidater og foresatte før test igangsettes.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE SITT SAMTYKKE

Det er frivillig å delta i prosjektet, og kandidater kan når som helst trekke seg fra deltakelse uten begrunnelse.

KONTAKTINFORMASJON

Eventuelle spørsmål om prosjekt eller deltakelse kan rettes til student Einar Lende på telefon 922 322 22 eller per email til elende00@uia.no.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class SceneChange : MonoBehaviour
{
    public float tWait = 2;
    public float t = 0;

    void Update()
    {
        // Increment timer
        t = t + Time.deltaTime;

    }

    public void Intro()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Intro");

        }

    }
    public void Scene1()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Scene1");

        }

    }
    public void Scene2()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Scene2");

        }

    }
    public void Scene3()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Scene3");

        }

    }
    public void Scene4()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Scene4");

        }

    }
    public void Scene5()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Scene5");

        }

    }
    public void Final()
    {
        if (t > tWait)
        {
            t = 0;
            SceneManager.LoadScene("Final");

        }

    }
}
```

USABILITY TEST PLAN DASHBOARD

AUTHOR

Einar Lende

CONTACT DETAILS

elende00@uia.no - Mob:92232222

FINAL DATE FOR COMMENTS

April 20th, 2020

PRODUCT UNDER TEST

MicroPop AR process application, guiding users on how to operate microwave correctly in order to cook popcorn safely and reliably.

BUSINESS CASE

Objective is to test application through trials with students, to improve User Experience and detect key improvement aspects before testing application on targeted user group.

TEST OBJECTIVES

Main goal for testing is mappig user affordability and usability improvement through feedback

Questions are divided into two sections (Pre-Test and Post-Test):

Pre-Test
Questions regarding AR and technology familiarity to establish user technology competence

Post-Test
Questions regarding experience during operating the application, with the aim of improvement through iterations.

PARTICIPANTS

5-7 participants requited

- All must be students at UiA
- Mix of men and women
- Age intervall (20-40 year)

EQUIPMENT

Laptop with internet connection
Tablet with AR applcation
Stopwatch
Coloured tape for position marker
Microwave
MicroPopcorn
Microsoft Forms - logging feedback

TEST TASKS

#1 Activate tablet

#2 Run application

#3 Point tablet camera at microwave to activate AR

#4 Go through steps 1-5 and perform tasks shown through AR

RESPONSIBILITIES

Einar Lende
Moderator, Interviewer and Data logger

LOCATION & DATES

May 1st, 2020
Health Clinig
Grømheia 20
4877 Grimstad

PROCEDURE

0-2min	3-5min	6-7min	8-9min	10-14min	15-20min
Welcome and introduction	Pre-test Interview	Application introduction	Test instructions	Carry out test	Post-test Interview and test wrap-up

User Test interview document, rev1.1

Participant _____

Pre-interview - Quantitative feedback

1. Hvordan vil du beskrive din generalle tekniske forståelse.

DÅRLIG 1	2	3	4	5 GOD

2. I hvilken grad benytter du smarttelefon eller nettbrett til å teste ut nye applikasjoner.

ALDRI 1	2	3	4	5 OFTE

3. Beskriv din forståelse og kompetanse rundt VR og AR.

DÅRLIG 1	2	3	4	5 GOD

4. Benyttelse av Augmented Reality applikasjoner.

ALDRI 1	2	3	4	5 OFTE

Post-interview - Qualitative feedback

1. Hvis applikasjon hjalp eller hindret deg til utføre oppgaven, beskriv hvordan.

2. Meninger om applikasjon løser problem den er ment for på en tilfredstillende eller utilfredsstillende måte.

3. Meninger om applikasjonen lærte deg noe du ikke var klar over.

4. Er det aktuelt/uaktuelt å benytte slik applikasjon flere ganger ved snakk om mer komplekse oppgaver.

5. Meninger om applikasjon kan gjøre hverdagen enklere/vanskeligere for brukere med nedsatt kognitiv funksjon.

6. Applikajonen benytter seg av video og produkt animasjon. Hvilken del fokuserte du mest på og hvorfor.

7. Vil lydsupplement med tilleggsinformasjon kunne forsterke eller distrahere under bruk.

8. Din mening om de 5 steg og eventuelle forbedringspotensial.

9. Andre forslag til forbedringer.

MicroPoP AR Applikasjon

Instruks for testobjekt

Utstyr

Du vil få tildelt 1stk nettbrett og 1 pakke med upoppet mikrobølgeovn popcorn til bruk under testen. I tillegg skal mikrobølgeovn benyttes til å utføre testen.

Testutførelse

Ved klarsignal fra testleder vil testobjekt få beskjed om å starte App MicroVu på nettbrett. Når kamera er aktivert i Appen skal bruker stille seg opp på anvist område og peke nettbrett mot mikrobølgeovn slik at mikrobølgeovn-animasjoner vises på nettbrett. Testobjekt skal deretter gjennomføre en 5 stegs operasjon, først vist gjennom nettbrett og deretter utført, steg for steg. Testobjekt må selv gå til neste steg etterhvert som del-oppgaver utføres. Test er utført nå siste steg er gjennomført korrekt i henhold til animasjon vist på nettbrett.

Testmål

Mål med denne testen er å følge alle 5 steg i applikasjonen, og utføre identiske handlinger mellom hvert steg. Sluttresultat skal bli en velsmakende pakke med popcorn som testobjekt kan beholde.

Testmonitorering

Selve utførelsen vil bli målt med stoppeklokke, observert av testleder og notater vil bli gjort under utførelse.

Sikkerhetstiltak

Av hensyn til Coronavirus-situasjonen vil alt utstyr bli vasket ned med antibakterielt middel mellom hver test. Ved tegn til sykdom og feber bes testobjekt å ikke utføre testen.

User Test interview document, rev1.1

Participant _____

Pre-interview - Quantitative feedback

1. Hvordan vil du beskrive din generalle tekniske forståelse.

1	2	3	4	5

DÅRLIG — GOO

2. I hvilken grad benytter du smarttelefon eller nettbrett til å teste ut nye applikasjoner.

1	2	3	4	5

ALDRI — OFTE

3. Beskriv din forståelse og kompetanse rundt VR og AR.

1	2	3	4	5

DÅRLIG — GOO

4. Benyttelse av Augmented Reality applikasjoner.

1	2	3	4	5

ALDRI — OFTE

Post-interview - Qualitative feedback

1. Hvis applikasjon hjalp eller hindret deg til utføre oppgaven, beskriv hvordan.

2. Meninger om applikasjon løser problem den er ment for på en tilfredstillende eller utilfredsstillende måte.

3. Meninger om applikasjonen lærte deg noe du ikke var klar over.

4. Er det aktuelt/uaktuelt å benytte slik applikasjon flere ganger ved snakk om mer komplekse oppgaver.

5. Meninger om applikasjon kan gjøre hverdagen enklere/vanskeligere for brukere med nedsatt kognitiv funksjon.

6. Applikajonen benytter seg av video og produkt animasjon. Hvilken del fokuserte du mest på og hvorfor.

7. Vil lydsupplement med tilleggsinformasjon kunne forsterke eller distrahere under bruk.

8. Din mening om de 5 steg og eventuelle forbedringspotensial.

9. Andre forslag til forbedringer.

Observation record form

Particimant number:

Task no.	1.Did it quickly 2.Did it with help 3.Did it with non-critical error(s) 4.Used too much time 5.Did not perform task	Time on task (Time to task completion in seconds)	Critical problems / Errors	Non-critical problems/ Errors
1				
2				
3				
4				
5				

USABILITY TEST PLAN DASHBOARD

AUTHOR
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CONTACT DETAILS
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FINAL DATE FOR COMMENTS
May 15th, 2020

PRODUCT UNDER TEST
MicroPop AR process application, guiding users on how to operate microwave correctly in order to cook popcorn safely and reliably.

TEST OBJECTIVES
Conduct application instructions

Evaluate app heuristics in terms of usability

PARTICIPANTS
2-3 experts requited

TEST TASKS
#1 Run application

#2 Go through introduction, steps 1-5 and perform tasks shown

#3 Evaluate user heuristics

RESPONSIBILITIES
Einar Lende
Moderator

BUSINESS CASE
Objective is to test application through trials, to improve User Experience and detect key improvement aspects before testing application on targeted user group.

EQUIPMENT
Laptop with internet connection
Conference equipment
Tablet with AR applcation
Microwave
MicroPopcorn

LOCATION & DATES
Mat 15th, 2020 14:30 at private facility

PROCEDURE

0-5min
Welcome and introduction

5-10min
Product test

10-25min
Panel Evaluation

Welcome as an Expert Test Participant

Introduction
As part of an expert panel for evaluating usability heuristics of the AR application microPOP, your participation is highly appreciated. During this session, you will have the opportunity to try out the App, from start to finish, and evaluate core aspects of the system. The purpose of this exercise is to identify areas of potential improvement within given criterias before proceeding with trials on targeted user group.

The Application
microPOP has been named microPoP, and involves a precise 5 step procedure for making "perfect popcorn" by using a microwave. The application has been designed with an specific user group in mind, ensuring an easy and safe way to perform the procedure to prevent accidents and other unwanted scenarios. Overall purpose of application is to guide users through steps by means of audio, visualization and practical repetition, both relying on their own motivation of wanting popcorn as well as by using positive reinforcement upon completion.

The User Group
microPOP is intended towards users suffering from mental disabilities such as Down's Syndrome or similar conditions. Their experience with handheld devices and AR technology currently not mapped, but dialogue with experienced caretakers suggest such devices are used frequently as both an aid, and means of personal entertainment. Their read/write skills are generally low, thus some prefer tablets with icons and numbering as aids.

Conducting Application Test
Prior to testing, you will be provided with a tablet, a popcorn package and a microwave. In your own time, you will execute the microPOP app, get instructions within the application and follow the steps provided through Augmented Reality technology to achieve desired outcome. Test will not be timed or monitored, and no personal information will be registered.

Post-Test Heuristics Evaluation
After conducting the test, you will be requested to evaluate 9 heuristic conditions pertaining to the design in a panel with other expert test participants. The 9 heuristics assessment requires qualitative feedback, in order to evaluate potential application improvements. A separate document is provided with guidelines for the assessment, and it is adviced that participants familiarize themselves with the guidelines prior to conducting the test.

1. Fit with user environment and task
AR experiences should use visualizations and metaphors that have meaning within the physical and task environment in which they are presented. The choice of visualizations & metaphors should match the mental models that the user will have based on their physical environment and task.

2. Form communicates function
The form of a virtual element should rely on existing metaphors that the user willknow in order to communicate affordances and capabilities.

3. Minimize distraction and overload
AR experiences can easily become visually overwhelming. Designs should work to minimize accidental distraction due to designs that are overly cluttered, busy, and/or movement filled.

4. Adaptation to user position and motion
The system should adapt such that virtual elements are useful and usable from the variety of viewing angles, distances, and movements that will be taken by the user.

5. Alignment of physical and virtual worlds
Placement of virtual elements should make sense in the physical environment. If virtual elements are aligned with physical objects, this alignment should be continuous over time and viewing perspectives.

6. Fit with user's physical abilities
Interaction with AR experiences should not require the user to perform actions that are physically challenging, dangerous, or that require excess amounts of coordination. All physical motion required should be easy.

7. Fit with user's perceptual abilities
AR experiences should not present information in ways that fall outside of an intended user's perceptual thresholds. Designers should consider size, color, motion, distance, and resolution when designing for AR.

8. Accessibility of off screen objects
Interfaces that require direct manipulation (for example, AR & touch screens) should make it easy for users to find or recall the items they need to manipu-late when those items are outside the field of view.

9. Accounting for hardware capabilities
AR experiences should be designed to accommodate for the capabilities & limitations of the hardware platform.

USABILITY TEST PLAN DASHBOARD

AUTHOR

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CONTACT DETAILS

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FINAL DATE FOR COMMENTS

TBD

PRODUCT UNDER TEST

MicroPop AR process application, guiding users on how to operate microwave correctly in order to cook popcorn safely and reliably.

TEST OBJECTIVES

Objective is to test application through trials on targeted user group, to validate hypothesis.

Questions are divided into two sections (Pre-Test and Post-Test):

Pre-Test
Questions regarding AR and technology familiarity to establish user technology competence.

Post-Test
Questions regarding experience during operating the application.

PARTICIPANTS

5-7 participants requited

- Mentally disabled
- Mix of men and women
- Age intervall (20-40 year)

TEST TASKS

#1 Activate tablet

#2 Run application

#3 Point tablet camera at microwave to activate AR

#4 Go through steps 1-5 and perform tasks shown through AR

RESPONSIBILITIES

Einar Lende
Moderator, Interviewer and Data logger

BUSINESS CASE

The application is meant to be used as an assistive technology towards the mentally disabled, guiding them through the process of making microwave popcorn.

EQUIPMENT

Laptop with internet connection
Tablet with AR applcation
Stopwatch
Coloured tape for position marker
Microwave
MicroPopcorn
Microsoft Forms - logging feedback

LOCATION & DATES

To be determined

PROCEDURE

0-2min	3-5min	6-7min	8-9min	10-14min	15-20min
Welcome and introduction	Pre-test Interview	Application introduction	Test instructions	Carry out test	Post-test Interview and test wrap-up

Targeted User Test Schedule, rev1.0

1. Welcome Test User

□□□□□□□□ **Appreciation for participating**
Thank participant for participating

□□□□□□□□ **General information on test purpose**
Purpose of the test is to help users perform their own household operations, with the goal being to avoid unwanted situations, increase safety and improve users self-reliance. This test is meant to generate feedback in order to improve the prototype through user feedback.

□□□□□□□□ **Technology Introduction**
Test participants will utilize a tablet, run and application and follow the steps provided through Augmented Reality technology to achieve desired outcome.

□□□□□□□□ **Test and privacy conditions**
Participation is voluntary, and participants can at any time withdraw from talking part. No names or other information that can identify individuals will be recorded during the process.

□□□□□□□□ **Health and safety**
All utilized equipment will be wiped down with alcohol based antibacterial products between each session to prevent any transmission of virus or bacteria between test participants

□□□□□□□□ **Cost and Reward for participating**
There are no cost involved, and all participants will receive popcorn as a reward for their participation

2. Pre-test Interview (Test interview document)

□□□□□□□□ **Participants technological competence of utilized hardware**
Mapping participants knowledge and competence level in regards to utilization of tablets

□□□□□□□□ **Participants comprehension of Augmented Reality software**
Mapping participants comprehension level in regards to Augmented Reality

3. Application Introduction

□□□□□□□□ **Introduction of MicroPop AR application**
The MicroPop application has been developed to show step-by-step instructions on how to produce optimal results when popping popcorn. MicroPop utilizes Augmented Reality to show a virtual microwave overlay on the real appliance. Users will get step-by-step instructions with the help of sound, animation and instruction video on how to achieve the end result.

4. Pre-test Instructions

□□□□□□□□ **Information about test sequence**
Test will be timed, observed, and general notes on conduct will be taken.

□□□□□□□□ **Cognitive walk-through of test**
Participants will be handed a tablet and micropopcorn, **1.** asked to run MicroPop application on the tablet, **2.** point the tabet at the targeted microwave, and **3.** follow and act on each sequence step provided by the application until completed result.

□□□□□□□□ **Goal of test**
To correctly follow each sequence step provided by the application, thus achieveing the result of optimally popped popcorn without creating any unwanted circumstances.

5. Test Performance Monitoring (Test notes document)

□□□□□□□□ Start Stopwatch upon test initiation, and stop after completion. Progress monitoring and note-taking.

6. Post-test Interview (Test interview document)

□□□□□□□□ Receive feedback from participants regarding application and general conduct of the test.

7. Test Wrap-Up

□□□□□□□□ Thank participant for conducting the test, and offer popcorn as a reward for completing the test. Wipe both tablet and microwave with alcoholic based antibacterial products to prepare for the next participant.

Participant _____

Pre-interview - Quantitative feedback

1. Hvordan vil du beskrive din generalle tekniske forståelse.	1	2	3	4	5	DÅRLIG – GOD
2. I hvilken grad benytter du smarttelefon eller nettbrett til å teste ut nye applikasjoner.	1	2	3	4	5	ALDRI – OFTE
3. Beskriv din forståelse og kompetanse rundt VR og AR.	1	2	3	4	5	DÅRLIG – GOD
4. Benyttelse av Augmented Reality applikasjoner.	1	2	3	4	5	ALDRI – OFTE

Post-interview - Qualitative feedback

1. Var det gøy eller kjedelig å bruke appen?

1. Beskriv noe som var vanskelig eller lett ved appen?

2. Er det aktuelt/uaktuelt å benytte slik applikasjon flere ganger?

4. Lærte appen deg noe du ikke var klar over.

5. Applikajonen benytter seg av video og animasjon. Hvilken del fokuserte du mest på og hvorfor.

Observation record form

Particimant number:

Task no.	1.Did it quickly 2.Did it with help 3.Did it with non-critical error(s) 4.Used too much time 5.Did not perform task	**Time on task (Time to task completion in seconds)**	**Critical problems / Errors**	**Non-critical problems/ Errors**
1				
2				
3				
4				
5				