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Requirement analysis for navigation application in a hospital

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Many people, who visit healthcare facilities, experience stress and anxiety. Visitors represent vulnerable user groups and may feel powerless and perceive the environment intimidating. Visiting a healthcare facility under emotionally stressful and physically debilitating environment, customers have only little capacity to deal with complex or confusing environment.

The objective of this project was to do a requirement analysis for augmented reality navigation application prototype for hospital use. Approaches used in the making of requirement analysis were user-centered design and service design. Garrett's elements of user experience laid the foundation in creation of the prototype. Development models such as waterfall development model, development cycle and the spiral model which fits this development work the best, were quickly introduced. Functional and nonfunctional requirements are discussed along with design requirements and customer requirements. Prototype development begun with information design where essential information was grouped to form an understandable structure for information. After information was grouped the paper prototyping was done with Figma, a user interface designing tool. Paper prototypes were shown to programmer who created the software prototype with Unity, Vuforia and QR codes combined.

The prototype had two separate test occasions and settings. Testers were interviewed with applied questions based on Nielsen's general heuristics evaluation. First testing tested the functionalities of the software. During the testing some improvements were made adding sounds and haptic feedback. The second testing was conducted in the natural environment, the healthcare center of Rauma where five testers tested the usability of the application prototype. Testers were volunteers who were chosen from different ages between 12-70 and the background in use of technology.

Tests were successful in many ways and the feedback from test users was positive encouraging further development of this application prototype.

Key words: augmented reality, QR code, navigation application, requirement analysis, user-centered design, service design, user experience

CONTENTS

1 INTRODUCTION

Many people, who visit healthcare facility, experience stress and anxiety. Visitors represent vulnerable user groups and may feel powerless and perceive the environment intimidating. Visiting a healthcare facility under emotionally stressful and physically debilitating environment, they have little capacity to deal with a complex or confusing environment (Carpman, Grant & Kirchen 2016, 24)

Use of information and communication technology has increased in various surroundings. Nowadays it is common to use different technologies in clinical nursing, teaching, continuing education and as management support. (Leino-Kilpi, Välimäki 2015, 386). Numbers of assisting personnel at hospitals and healthcare centers has decreased and automated self-check in points have become more common. Hospitals are being centralized and sizes of hospitals are growing in many areas. This has opened an opportunity for guiding systems to assist customers alongside with the traditional guiding signs.

This AR guiding application takes advantage of the technological advancements and benefits the hospitals staff when familiarizing personnel to new working environment and customers/patients of healthcare center. In the best possible scenario, it can reduce time spent on guiding customers to find the right place and help patients to keep their appointment times accurate without delays caused by getting lost.

Finnish Government aims to digitalize healthcare services to support health and well-being. The Ministry of Social Affairs and Health published guidelines for digitalization 2025. In those guidelines it was noted, the digitalization changes the world quickly. It creates new options to choose from to overcome challenges of Finland when the population ages. People need more support for health and wellbeing and at the same time financial resources are limited. It creates a need to come by with reduced financial resources. This requires more productivity, efficiency and cost-efficiency and

electronic ICT solutions is one option for increasing efficiency and effectiveness. Digitalization changes ways of doing the work, its contents and it should not be forgotten that digital services are self-evident for the new generations. One of the guidelines of Finnish Government is to provide smart information systems for the personnel which support the processes and are usable (STM 2016, 4,18).

2 BACKGROUND AND PURPOSE

Journey to healthcare facility can be stressful and confusing. Decisions need to be made about traveling, parking, finding the main entrance, getting oriented inside and finding the first destination. (Carpman, Grant & Kirchen 2016, 84)

Need for technology rises from the needs of people. Products and services need to be designed considering people and their life situations. Values and attitudes of life influence these endeavors but so do also the possibilities and limitations, which are thoughted to be gained with use of the developed technology. Decreased mobility and use of senses, delayed reaction times as well as decreased motor skills can lessen the possibilities to use technologies. Different needs have to be considered when designing technologies, to have an understanding of real life and to include users and stake holders to the design process in different phases. The point of view has to be very wide in the designing process and the functionality, dependability, accessibility and safety needs to be considered in the designing phase (ETENE 2010, 26-27).

The purpose of this thesis is to create a mobile application prototype which helps the staff/patients/customers to find the right places inside a hospital building and to test the application in the Rauma healthcare center. Hopefully this application could be of assistance to many in the future.

The goal of this thesis is a requirement analysis for the navigation application which helps employees/customers to find right places inside the hospital. The aim is to create a paper prototype and secondly the actual prototype for the mobile device as a support

service for customers and personnel. The testing of the prototype is going to be conducted by volunteers of different ages and knowledge on technologies as well as the different level knowledge of the facilities.

3 KNOWLEDGE BASE

There are several different approaches which can be used when designing new services. Service design is a process with the aim of ensuring the quality of the service being created. Service can be a new service, or it can aim to improve an existing service.

3.1 Requirement analysis

Requirement analysis is a process where the principles and preconditions are documented. Documented service design and it´s requirements decrease uncertainties concerning realization of the process. Requirements analysis requires writing and focusing (Tonder 2013, 103-104) Requirements describe what the software needs to fulfill to be successful (Arnowits, Arent & Berger 2007, 574)

3.2 Various approaches in making requirement analysis

3.2.1 Service design

Service delivery systems are nowadays dependent of platforms, but the quality often suffers because of the complexity of the systems and this is why service design has a specific design approach. In the introduction of new technologies, a good service design is a key to success and services can be redesigned continuously. Service as a performance and service as a value both describe the success of the service. Service performance is a success if people describe the service as good. Value is a success if it is achieving the promised results for customers and if it is performing for the organization (Polaine, Lvølie & Reason, 2013, 24-28)

Customer experience and value should be equally important for the designer and the ability to develop cheap prototypes can save organizations enormous amount of money. Services are provider - customers relationships and in the future, the customer should be recognized as co-producer of the service (Polaine, Lvølie & Reason, 2013, 32-37)

Experiences of the service users are hard to defend in the hospital environment because of the medical matters must take priority, but context of experiences is where the service design works. Service design can contribute to the effectiveness, positive economic results, successful operations and beneficial policy outcomes. Services must change according to customers' needs over time (Polaine, Lvølie & Reason, 2013,131-160).

Services build based on insight can deliver real value for people using the services. The main aspects of service design are the interactions between people and their motivations and behaviors. The challenge is to redesign the service and the organization culture. Services are creating only value when the services are actually used. (Polaine, Lvølie & Reason, 2013, 19-23)

One of the tools to create a vision for complex factors affecting an organisation is a context canvas (Curedale 2013, 278) The following context canvas was created considering a health care organization in Finland at present time. Canvas helps to structure the service, plan ahead and to gain an understanding about the service being created. With help of these canvases like in figure 1, many viewpoints can be covered minimizing the factors that possibly wouldn't be considered in the planning phase.

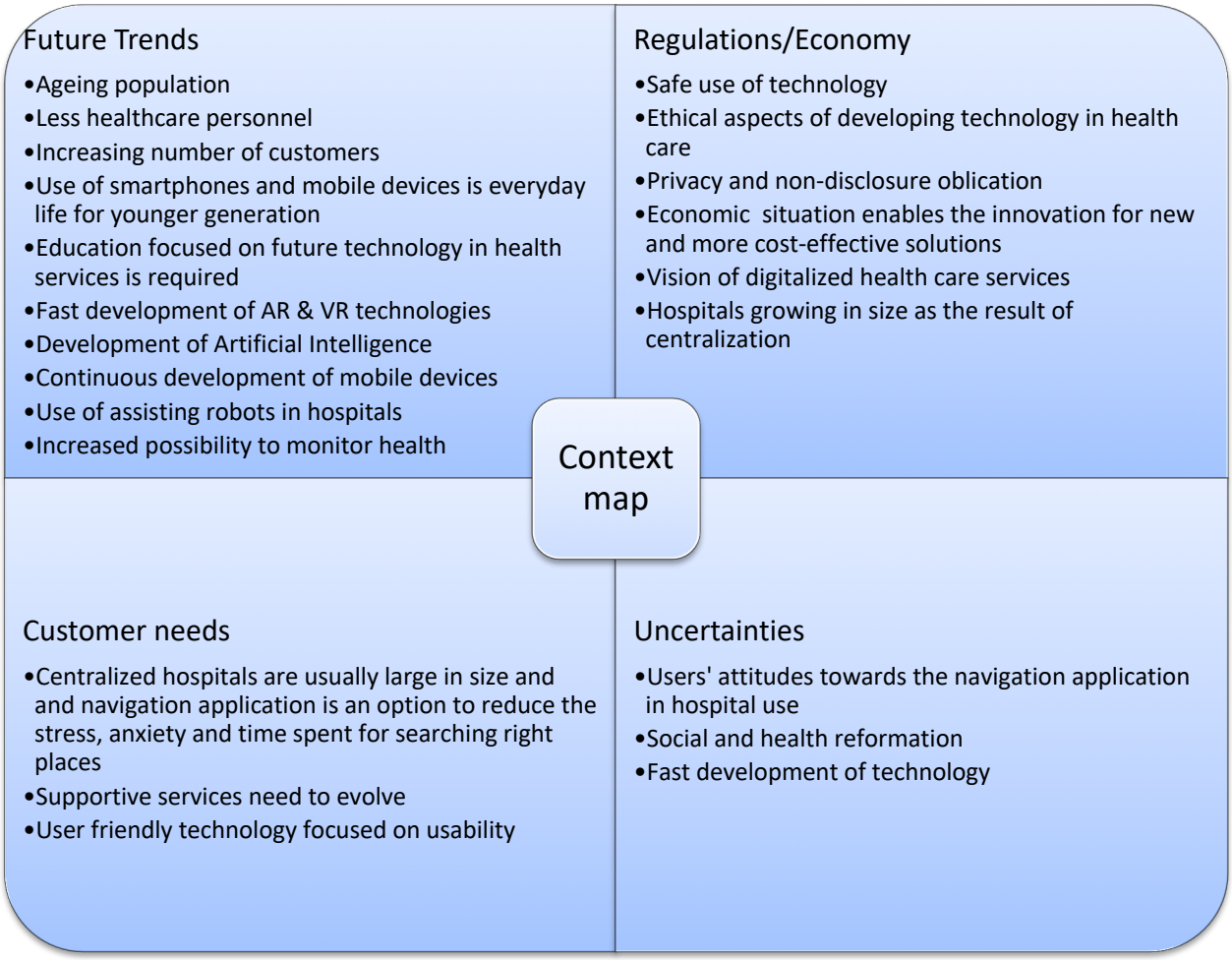


Figure 1. Context map

By adding a value proposition map like in figure 2, we can get more detailed understanding of what problems need to be solved. Value proposition describes what value the solution brings to the customer (Toiminen, Nevanlinna, Sarvas & Mutikainen 2018, 152). In this project the solution is navigation application.

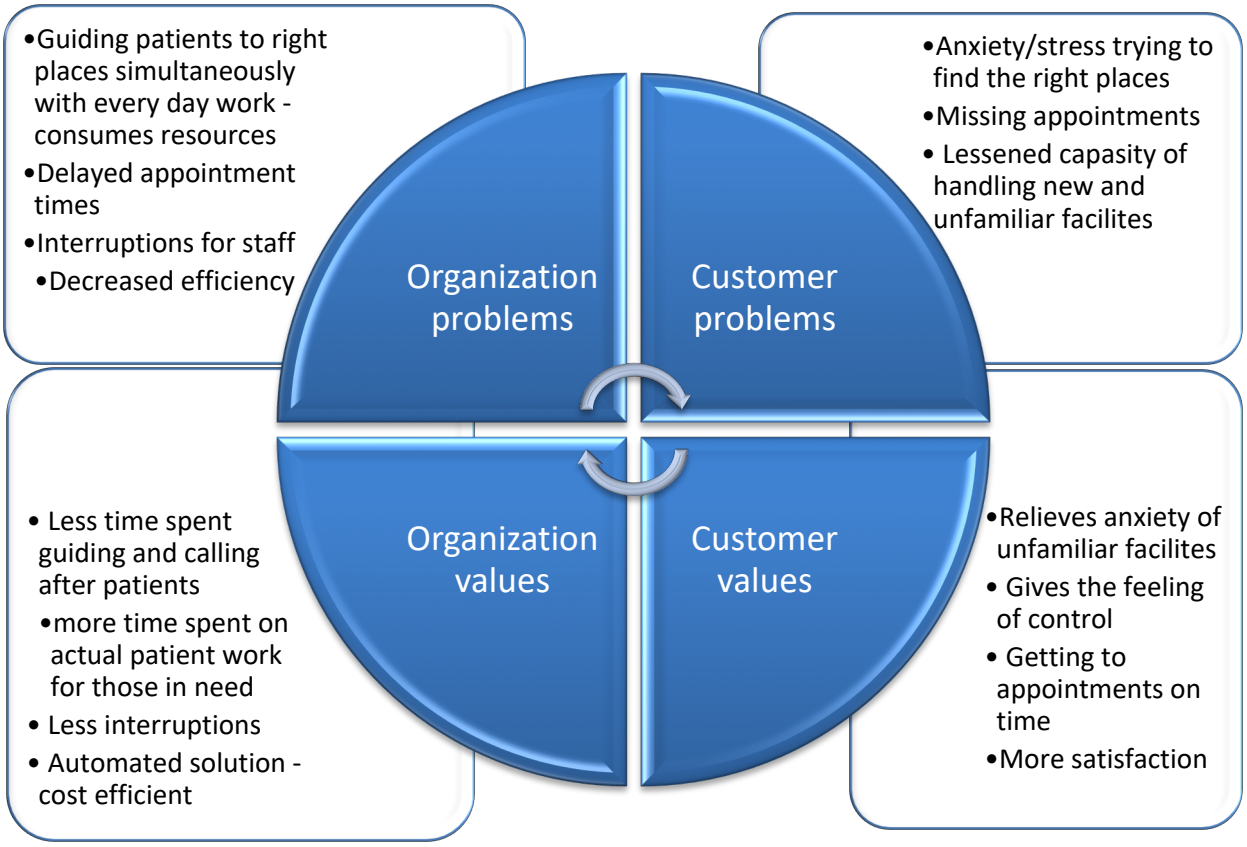


Figure 2. Value proposition map

3.2.2 User-centered design

The aim of keeping user in mind is called user-centered design in the development process and the reward of it is increased efficiency. Effective tools help people work faster and help them make fewer mistakes and improve the productivity (Garrett 2011, 15-17)

Red-green colour-blind people, people with weakened motor skills and the ability to walk are factors which effect the process among others. Aim is to create an application which can be accessible for as many people as possible.

Garrett 2011 has demonstrated the elements of user-centered design as seen in figure 3. When designing usability, there are five levels which include certain aspects. Starting from abstract strategy level from user needs and product objectives the elements of user experience proceed to scope level which includes functional specifications and content requirements. In the middle of abstract and concrete lies the level of structure

with interaction design and information architecture followed by the skeleton level of information design including interface design and navigation design. The most concrete level is sensory design on the surface level. They are overlapping in many areas and they all effect on each other.

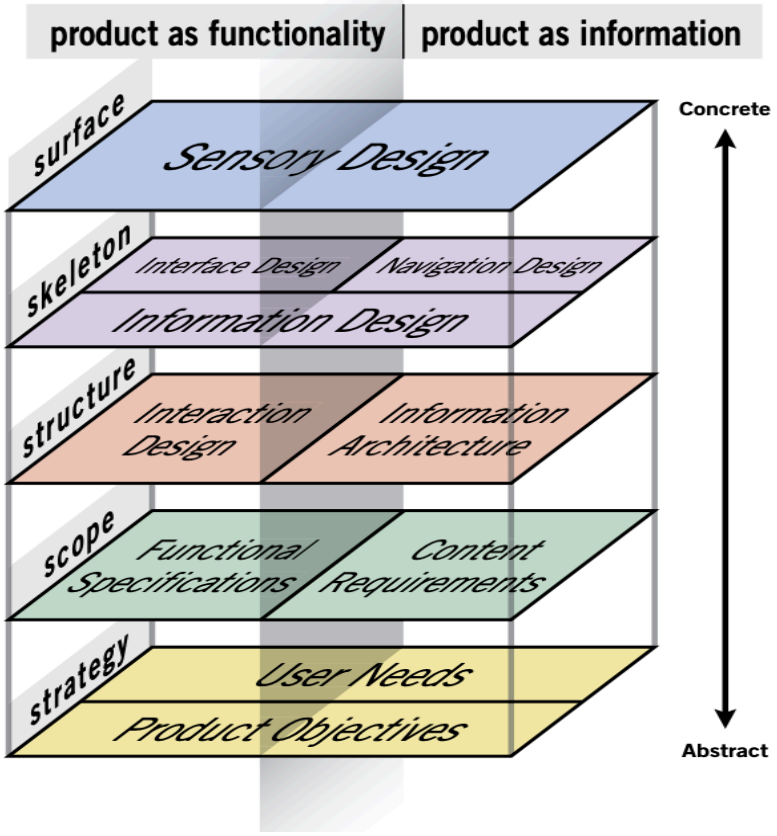


Figure 3. The elements of user experience (Garrett 2011, 29)

3.2.3 Development model

There are different development models which could be used in the software development process. One of them is waterfall model. Waterfall model begins with requirements gathering followed by development steps finishing to maintenance in which the development process ends.

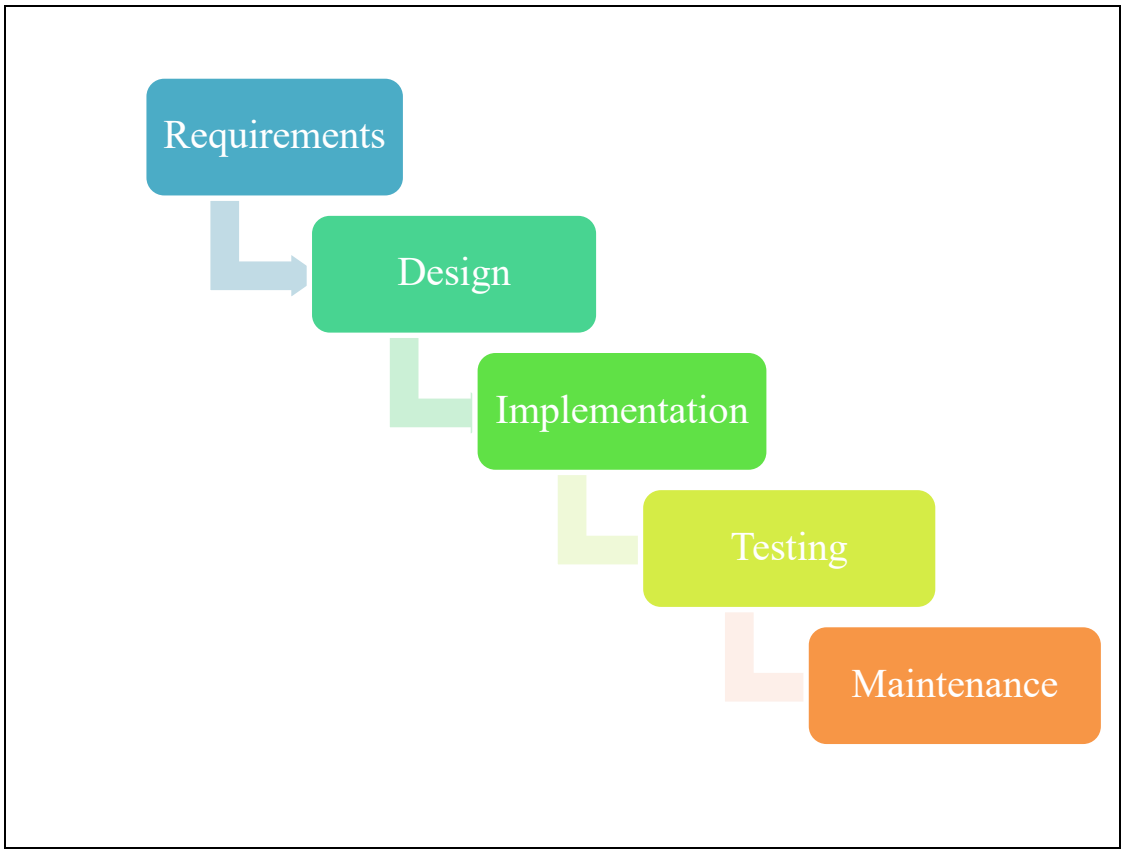


Figure 4. Waterfall model (adapted from Peter Kemp & Paul Smith 2010, Winston Royce waterfall model, Wikipedia)

Development cycle is a model which could be used in the software development. It starts with planning followed by analysis, design, implementation, testing and integration. A cycle has the ability to start from the beginning unlike the waterfall model which ended to the maintenance phase.

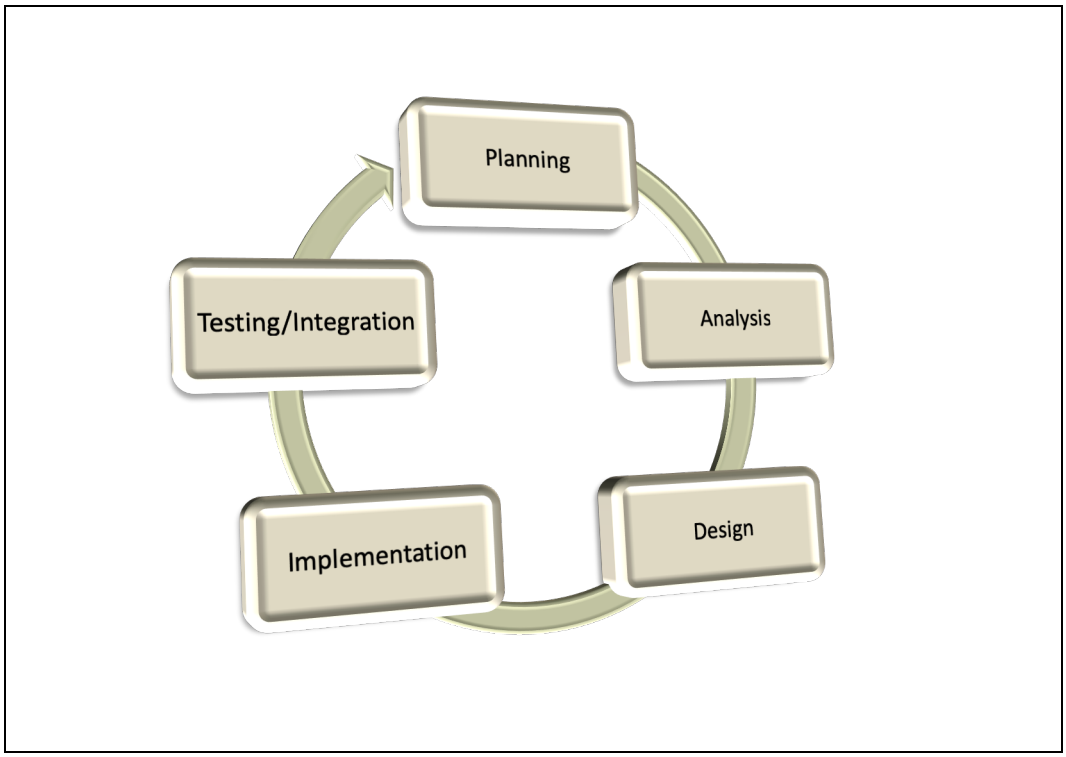


Figure 5. Development life cycle (modified from Ample WebSol 2018).

A spiral model was chosen for this development process. Planning, action, observation and reflection spiral after one another getting back to the beginning where the spiral starts again. The process in this project needs many rounds to get to the testing and role of reflection is vital. Below a picture of spiral development cycle.

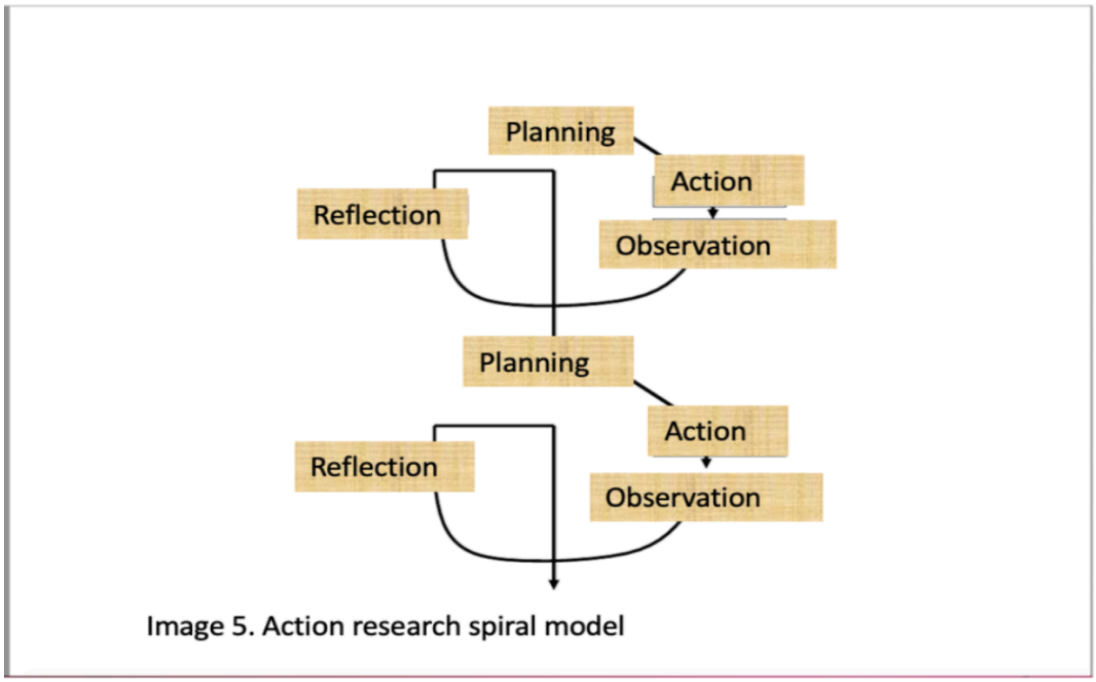


Figure 6. The spiral development model Toikko & Rantanen (2009, 67)

3.3 Various solutions for AR guiding applications

When exploring the possibilities of the technologies which could be used in this project making the navigation application prototype, there were interesting studies conducted of the subject. These studies provided an understanding of the technologies which could be used together. There are various studies of similar applications and these studies have same elements used in the planning of the application. Those elements are QR codes, Augmented reality, Vuforia and Unity 3D.

Finnkino, a Finnish movie theatre in shopping centre of itäkeskus, uses AR application guidance in theatres providing more information about sold products and places (Finnkino, 2020). Town of Uusikaupunki in Finland has AR guiding application under development for historical guided tours and the plan is to have it in use in the summer 2020 (Uudenkaupungin sanomat, 2019). Same kind of application has been created in Norway, introducing the tourists historical places of Oslo (Weiqin 2014) and Hautamäki (2013) developed a location based augmented reality application as part of already existing mobile software which operates as public transports route guide. The application uses augmented reality-based view to guide user to the point of interest.

Stolt (2015) looked into the possibilities of mobile application supporting guidance. Surveys were targeted for shopping center customers and users of hospital services. Results showed there was a clear difference with these two groups. Shopping center customers knew about these kinds of applications and hospital service users did not. Over half of people, who answered the survey, were interested in this kind of guidance system. QR and NFC technologies can be used to load information from the information board, and it could be used to bring more information to guidance in different parts of the buildings. Happonen & Oinonen (2013) researched what kind of attitudes, beliefs and knowledge students of Jyväskylä university of applied sciences had towards augmented reality and its applications. The main concern was the lifespan of applications. Majority was ready to try the applications but just for amusement. Applications must feel practical, natural and voluntary for their lifespan to be extended. The focus group would not buy augmented reality applications

Chapagain's (2018) thesis was one the reasons Unity 3D and Vuforia were chosen to be used as development tools in this project. The main goal was to build a demo application based on Vuforia library and Unity 3D because of its simplicity. As the result, the application was developed in three weeks with open source objects and improved by adding the scripts. Two usability evaluations were conducted to receive feedback for further improvement. Results showed a general positive attitude among users. They were particularly enthusiastic about the possibility of viewing historical pictures and information when pointing camera towards buildings.

Before application development, the literature review gave suggestions for application development tools by presenting different options which could be used. These tools were presented to a programmer of ScientialTech programming house and discussed. The main point of these conversations was the technical expertise of the programmer and his opinion on if these tools were fit for this purpose.

3.3.1 Augmented reality (AR)

Augmented reality is a general term and it can be applied to a variety of display technologies which are capable of overlaying or combining information such as alphanumeric, symbolic or graphical with user's view of the world (Austakalkanis 2017, 2) Simplest definition of augmented reality might be definition of Augmented reality as technology which enables the addition of virtual content to the real world (Habbak & Cushnan 2013, 20).

Augmented reality is three dimensional surrounding and virtual object utilizing technology. Augmented reality brings objects created by a computer on top of the real worlds view, while deploying different displays. The computer created objects can be three dimensional objects or added information about a place in text, video or picture material. The displays can be mobile phone screens, data glasses, traditional screens or projections to the space. Augmented reality can be thought of as new kind of interface to connect real world with digital world (Kalalahti 2013, 5-34).

3.3.2 Quick response code (QR)

QR Code is a two-dimensional code and QR is abbreviation of the words Quick Response. Two-dimensional means it can store data horizontally and vertically and QR code usually consists black and white square modules and construct a square. It was originally created by Toyota Japanese affiliated company Denso Wave in 1994. There can be 7089/4294 numbers/letters in one QR Code and about 500 characters would still make it readable to mobile phones. QR Codes can be scanned/read with mobile phones, tablet computers, laptops, desk computers and QR (Pihkala 2018, 10-15).

Qianyu´s (2014) study concentrated on the concept of QR code and the benefits of using it for companies. QR codes can be read in 360-degree direction and in high speed. It is capable of storing various types of data e.g. numeric and alphabetic characters, Kanji, Kana, Hiragana, symbols, binary and control codes. QR code can immediately connect people to virtual environment of information and entertainment. QR code has the error correction capability so the data can be recovered even if the code is partly dirty and damaged (30%). One interesting feature is that several QR codes can be stored in one QR code and read at the same time.

There are five kinds of QR Codes. Original QR code which stores information vertically and horizontally, Micro QR code which is smaller and stores maximum of 35 numerals, iQR code which can hold 80% more information compared to regular QR code , SQRC which can carry private data and information can be restricted to be read by specific devices and FrameQR which can hold an image alongside with QR code (Denso Wave, QR Code.com).

QR Codes can be used for free so it is affordable and can bring considerable value for organizations. QR Code is widely spread and used in number of fields such as newspaper, magazines, advertisements, restaurants, clothes stores, social network applications, by governments and enterprises.

3.3.3 Unity 3D and Vuforia

Unity is developed by Unity Technologies. It is a cross-platform engine for game development. It is most popular engine with more than million developers due to its ease

of use, productivity being high and a free version to be used. It can deploy many different platforms (Habbak & Cushnan 2013, 34).

Vuforia software development kit is multiplatform framework leading AR/VR software development and providing all necessary tools for AR/VR applications. It was originally founded by Qualcomm and sold to PTC in 2015. Vuforia is easy to use since all components are widely tested and designed for fast development. Vuforia includes all most important technologies for AR applications such as ground plane detection, image detection, object scanning and tracking. All this makes Vuforia widely used in commercial applications (PTC 2020; Vuforia 2020)

4 MOBILE DEVICE APPLICATION PROTOTYPE DEVELOPMENT

This project follows in the footsteps Garrett's (2011) model of user experience to ensure the usability of the application. It keeps the user in the centre of the development process. It all starts with user needs, product objectives and strategy. These are dived to functionalities and information; one cannot succeed without the other. Careful planning ensures the integrity of the design.

4.1 Customer requirements

The intent is, the use of this application/program is via customers own device and not provided by the health care centre. Focus groups are the customers, patients and the employees of health care center at Rauma who use health services or work in the facilities. In this particular project, testing of the prototype is going to be conducted with health care center employees and visitors chosen beforehand. This application is designed for the people who are able to use smartphones without great impairments with vision or motor skills.

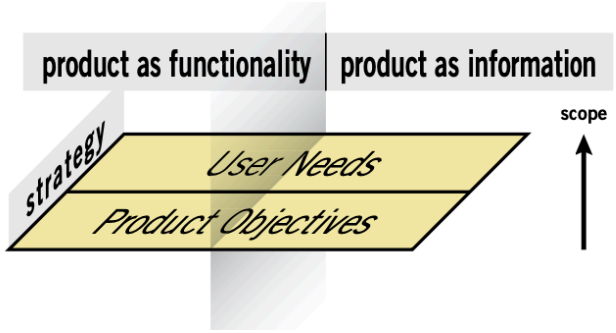


Figure 7. User needs and product objectives (Garrett 2011, 30)

This project of creating navigation application was a result of negative user experience navigating in unfamiliar hospital facilities. Planning on the strategy level starts with user needs and product objectives. From the user's point of view, the application should be easy to use, to ease possible anxiety in hospital environment which might also be unfamiliar environment, to find right places and to complement the existing traditional guiding inside a hospital. The user needs to have essential information available of the services in the facilities, where to go and how to get there. Usability means using the application is easy, the use of the application can be understood without external instructions, it should be easy to learn, it should be effective, and the use of the application should be satisfying.

To use this application, one needs a device, a smart phone or tablet. User has to be able to hold the device and follow simple instructions. User needs to have motor skills in the fingers good enough to press intended buttons and be able to target camera towards the QR codes.

Application being developed is an application designed for hospital use for its employees, customers and visitors. It is a guiding application which uses QR codes and augmented reality. This type of application has been a good subject for many theses, but none of them have been implemented to hospital surroundings.

4.2 Functional requirements

Functional requirements means things the system should do. Gathering functional requirements and content requirement clarifies what you are building on a strategy level (Eriksson 2012, Garrett 2011 59,60).

Smartphone and internet access is needed to use this application and it can be used by employees or customers. First when camera is pointed towards the QR code at the entrance door, application opens with instructions welcoming user to healthcare center. By starting to use the application, first layout opens. It lets the user choose where he/she wants to navigate or be guided to by selecting a place from a list. More specific list opens and lets the user choose the exact location and "start navigation" button appears. If Yes is chosen, it starts guiding towards the user's destination of choice. Other option is to choose another location or stop using the program. When guiding is ongoing, the camera searches for the QR codes to update the location of the user and draws a yellow arrow to point to the right direction. There is an option to stop the guidance at any time. When user arrives at the wanted destination, the application informs the user and asks, if the navigation should be stopped, or if the user wants to move forward to another destination.

Functional requirements list

The list of functionalities gives a good understanding about what the application can do. Functionalities are listed, and details are explained as seen on figure 6.

List of functionalities
It has to be able to:

- To read QR-codes;
  - To read only specific QR codes to this program
- Search automatically QR codes
- Give instruction to use the application
- To display location options
- To choose locations from the lists.
  - Main lists and
  - Detailed list
- To have easily understandable error messages
- To recover fast from errors
- To give clear instruction if error occurs such as “start from the beginning” or “find the nearest QR code and point your camera towards it)
- To provide “undo” button (incase screen is touched or swiped to get back to navigation)
- To navigate according to the QR codes
- To get back to the navigation, if the phone rings in the middle of the guiding, and
  - let phone calls through
- To present a clear AR navigation guiding pointer
- To stop the use of the program at any time
- To change location information at any point
- To have buttons big enough to touch,
  - Button on the screen about 1-2x4cm
- The word count should be from 1-20 words, more could make the program harder to use
- Clearly inform when the destination is reached

Figure 8. List of functionalities

Content features should be updated depending on the strategic goals set earlier. Error messages should be provided and a way to recover from those errors. Error recovery can take different forms, but the best-known example is an undo function (Garrett 2011, 72-87)

In this particular application the updates should be done every time there is a change in location of the clinic or ward. Error messages need to be clear, easy to understand and easy to recover from. Choice of starting the navigation from the beginning should be added or undo the step which was not intended. An undo button does not exist in the same sense than mentioned earlier but person using the application can stop navigation at any time and choose the same location again and continue to the destination.

Feature set

Feature set is a detailed description of the product and it´s various content elements which are required (Garrett 2011, 29) Gaming technology enables the development of different applications outside the gaming genre. In this application prototype less is more. The aim is to keep it as simple as possible to ensure the usability.

Feature sets

Navigation options:

- Choose a place to navigate to from the main list
- Choose the exact location from the detailed list
- Choose to start navigating or exit to the main list

Colours:

- Blue
- Yellow
- White

Images:

- Buttons, scaling according to device
- Arrows big, stays on screen for 7 seconds
- Short instructions

Signals:

- Two signal sounds when finding QR code
- Three sounds when reaching the destination
- Haptic feedback, short buzz

Background:

- Natural environment

Figure 9. Feature sets

4.3 Usability, User experience

Non-functional requirements specify how the system should behave and describe how the system works. Such requirements can be seen as quality attributes for a system. Usability, security, reliability, availability and performance are few of such quality attributes (Eriksson 2012).

Experiences are personal and subjective and cannot be observed directly. Experiences depend on persons internal state and the context. Experience driven design involves determining what experiences to aim for and engineers need thorough insights in everyday user experiences. User experiences can be the starting point for innovative design processes (Schifferstein, Sleeswijk Visser 2013, 81-95) The design approaches used in this project aims to make the experience of using healthcare center facilities pleasant by helping the user to gain a sense of control of the environment and to ease anxiety of visiting unfamiliar places.

Usability contains multiple components such as learnability, efficiency, memorability, errors and subjective satisfaction. Learnability refers to ease of learning to use the program and it is easiest to measure. Efficiency can be tested by asking test users to do certain tasks and timing it. Memorability means the interface being so memorable, that users who have not used it in a while, are able to use it. The possibility of making errors should be as minimal as possible. Subjective satisfaction describes how pleasant it is to use the system and it can be measured by asking opinions of the users (Nielsen 1993, 26-36)

Simplest possible user interface is the guarantee of usability in this application. The application needs to be pleasant to use and learning to use it should be fast, not time consuming. It should be easily accessed when entering the building

4.4 Design requirements

Design requirements in this application development consists interface design, navigation design, information design, interaction design and visual design.

Information design, navigation design and interface design all meet in the page layout and all of them represent different viewpoints of the architecture. Uniformity is an effective way to communicate and has a role in visual design. (Garrett 2011, 128-141)

First QR code can be found from the entrance door and the next soon after entering the building. QR codes are placed to the wall of the hospital’s corridor, preferably on the left side. The height from the ground up should not be lower than 122cm and not

higher than 152cm to ensure the possibility of wheelchair users to have access to QR codes among the others (Iowa State Workforce Development Board 2017, 15; ADA checklist for existing facilities by the institute for human centered design 2014). The distance between QR codes should be 10-15m and if needed. Sizes of QR codes should be smaller than paper size. Testing should reveal what size QR codes can be used. Contrast from the background needs to be clear.

Interface and navigation design

Skeleton level describes forms of the functionalities. It defines details and individual components and their relationships (Garrett 2011, 108)

Interface design is in question if it provides the ability for user to do things and allows to get in contact with functionalities defined in the interaction design. Interface design is about arrangement of the elements to enable interaction. It includes navigation design, elements how to move around the product, and information design, how the elements communicate the information to user. When designing an interface, the selection of right elements is vital. Interface is a success when the user notices important elements right away, it is easy to understand and easy to use. One of the simplest ways is to think carefully which default options are presented to the user (Garrett 2011, 109-134).

Interface is going to be designed simple and easy to use. Only essential words/texts are going to be available. Action buttons are going to be used and only if a must, there is going to be dropdown lists added. The main aim is to be consistent. Choices, which user can make, need to flow logically from one to another without too many options to choose from. Every button needs to have essential purpose.

There are three goals the navigation design should meet: 1) means to get from one point to other 2) it needs to clarify the relationships between the elements and 3) to communicate the relationship between the content of the page and the page the user views. It helps to understand which option available helps with choosing the right options to reach the desired goals (Garrett 2011, 119). One fundamental concept of navigation is consistency. It helps to visualize the location, options and reduces guessing. Predictability of navigation makes users feel comfortable giving the sense of order

(Nielsen 2006, 178) In this hospital navigation application, the navigational aspects are considered as minimum number of buttons to push and features to choose from. All are well thought and put together after serious consideration and the logic remains the same in every layout.

Information design

On skeleton level information design presents, how the information should be presented so, that people could use it and understand it. It can be visual charts or information arranged in groups. Used language should be consistent and a controlled vocabulary could help with that. Controlled vocabulary is a set of standard words used. (Garret 2011, 98-124) Designed tasks have an impact on effectiveness of the service. If the words, layout or user interface are confusing, the user tends to turn to different services (Polaine, Lvølie & Reason 2013, 133)

The information needed is the information of services the health care centre provides and locations of those services. By grouping the information and drawing a map these can be deployed in the prototyping phase. The language used is going to be typical healthcare vocabulary accompanied by simple words such as “start” and “quit”.

Interaction design, visual design

Interaction design aims to describe the possible behaviour of the user and is part of structure level. Interaction design defines how the system responds and accommodates to that behaviour (Garrett 2011, 81).

Requirement for interaction design is the simplest possible approach on touch screen. Buttons are big enough and choices are logically grouped. Easy logical access, the possibility to alter the made decision or to cancel the whole process and change the course if needed. Program should provide feedback to the user, for example, when pushing a button, a button would react, and this way provide feedback to the user. User would know pushing of the button would be registered and it would eliminate guessing.

A contrast in colours is the primary way to draw user’s attention to the essential aspects of the interface. (Garrett 2011, 158) Yellow, red and orange are the colours which stay

in the memory and peoples' perception of those colours doesn't change much over time. Blue, purple and turquoise weakens over time. Dementia weakens the ability to see white when the disease progresses until it cannot be seen any more. Colours can rise emotions and feelings. Yellow is perceived as sunny, happy and light colour, blue is relaxing, calm, fresh and cool (Sievänen, Sievänen, Välikangas & Eloniemi 2007,22)

When designing user interfaces' visual look, the choice of colour and style was quite obvious after a little consideration. Colours and style should follow the styles and colours of Rauma, which are used in official web pages even if they are not exact. Those colours are Yellow/orange and blue and embody sunny, happy and light, relaxing, calm, fresh and cool colours. Suites for this purpose very well.

Requirement for interaction design is the simplest possible touch screen. Buttons should be big enough and choices logically grouped. Pushing of a button creates feedback from the application as haptic feedback and sound. The application gives feedback every time it sees a QR code and when the destination has been reached. User can choose whether she/he wants the navigation guidance with a sound or only with arrows and haptic feedback.

The feedback sound was decided to be a xylophone for its sound is clear, soft and not disturbing. simple 1 sound when choosing a place from the list, 1 note sound when finding a new QR code and 6 ascending notes when final destination is reached.

4.5 Other requirements

This application needs to be maintained easily, there needs to be a possibility to add or change locations as often as needed. The use of this application needs to work without glitches to avoid frustration from the users' part. Software needs to run in the user's own device and own internet connection to ensure, the health care centers internet connections/information systems, would not be compromised due to this application.

This application is a prototype, so it is not expected to work as well as a fully developed and functional application. One of the requirements from the beginning has been the

requirement of affordability. The introduction and the utilization of technology is usually expensive for the organizations (Leino-Kilpi, Välimäki 2015, 387) which is why QR codes were chosen for this project combined with AR technology. These can be used in a developing phase for free with Vuforia and Unity software development platform. Only costs are supposedly the paper needed to print QR codes on.

Finnish health care system is facing many challenges and it encourages to think of cost- effective implementations. With this application, it means the lowest amount of money to be used in the development phase as well as in the use of the application. The development of this application should be free or at least should not add to the existing costs of the programs in use. The time used planning and developing is not included, rather taken as an opportunity to learn. If this prototype is going to be developed and taken in to use, there are going to be some fees concerning the licenses of used programs.

5 PROTOTYPING

Prototype is a design specification used as a way to communicate final design to developers. There should be awareness about the fact that not every aspect of the prototype should be replicated in the final system (Nielsen 1993, 99).

Using paper mock-ups are usually based on printout screen designs, dialogue boxes, pop-up menus etc. which have been drawn in standard graphics (Nielsen 1993, 97) Many designers find themselves exploring their ideas using traditional paper methods due to its speed and ease of implementation. Sheets of paper can be used for paper prototyping as well as D6 dice, cards and card sleeves. (Bond 2018, 130-131).

5.1 Information design

First, the information of clinics and wards were gathered and organized, to gain an understanding of what services are offered in the building of Rauma healthcare center. Grouped services are demonstrated in figure 8.

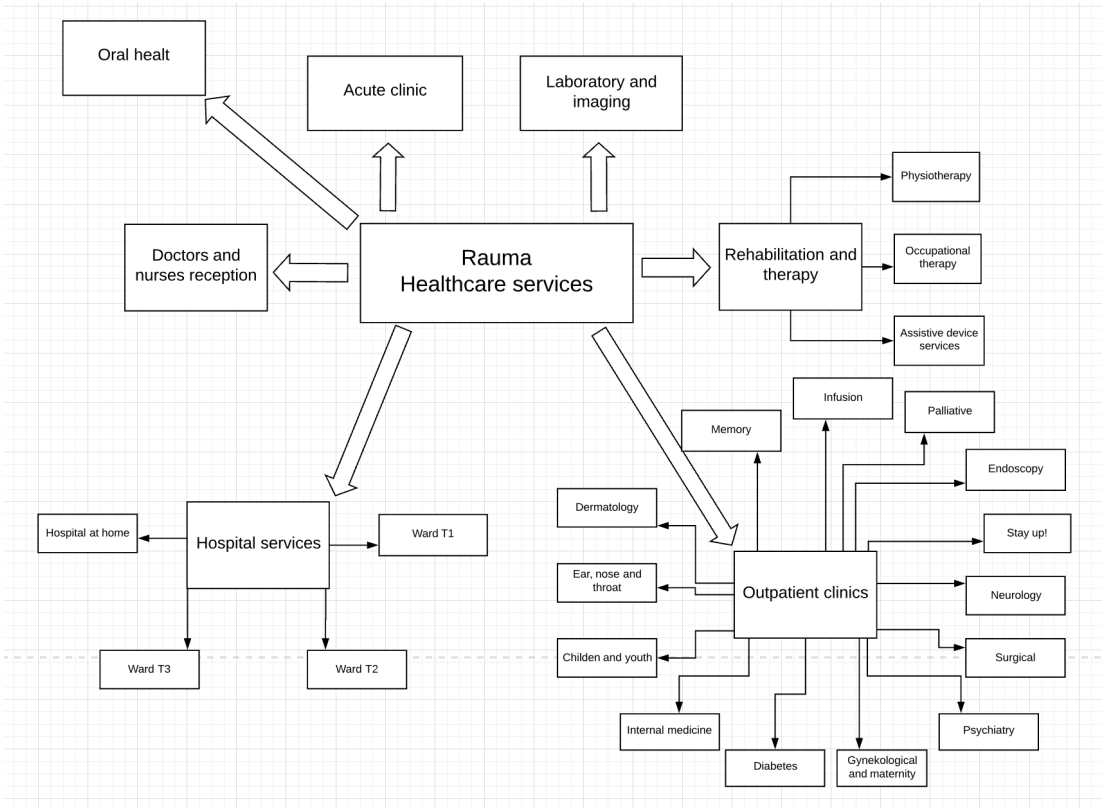


Figure 10. Services of Rauma healthcare center

After grouping the services, it was time to consider where this application would be tested, and so, which parts would be included. It was decided to conduct testing of the prototype on one level, the second floor, which contains many outpatient clinics.

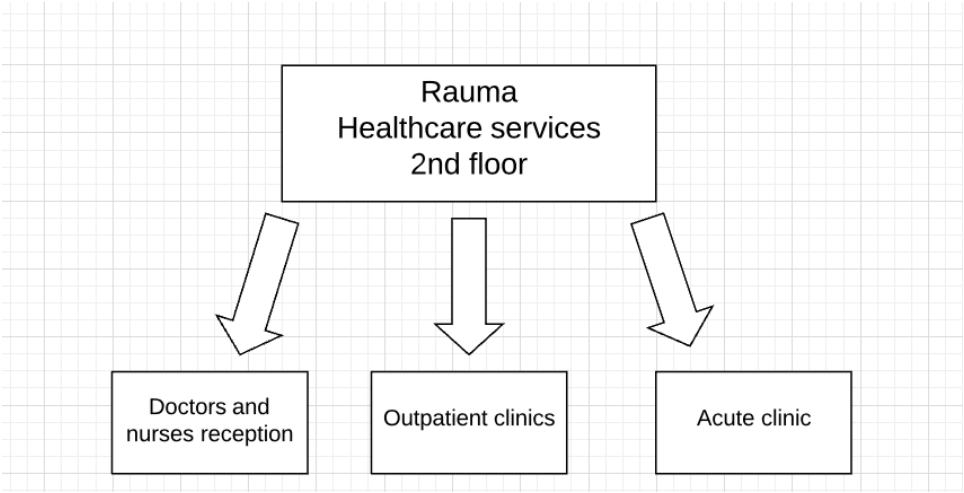


Figure 11. 2nd floor services

After mapping the main services, it was time for more detailed mapping. Results can be seen from figure 9. Acute clinic, nurse's and doctor's reception and self-check-in points are fairly easy to find, but there are many outpatient clinics which are located in different parts of healthcare center.

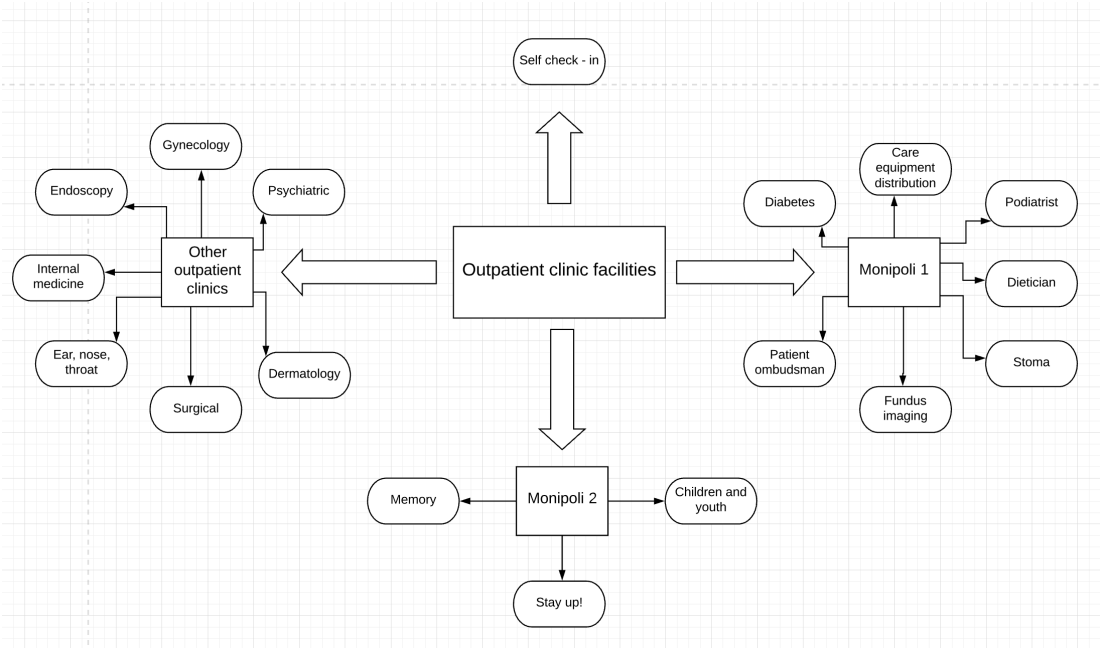


Figure 12. 2nd floor services in detail

5.2 Prototyping with technologies

Prototyping of this mobile application begun with an understanding of the fact, that there needs to be a platform to create the content and user interface to. Few options were seen to. Paper prototyping was the first method which was considered, and there was a need for electronic platform just to get a learning experience. It needed to be free of charge or at least not adding to the costs of programs which were already in use. Tool that was chosen to be used was Figma. It had the features needed to design the user interface. Tutorials of the use were short and easy to follow. A link to actual prototype could be sent straight to the application developer/programmer.

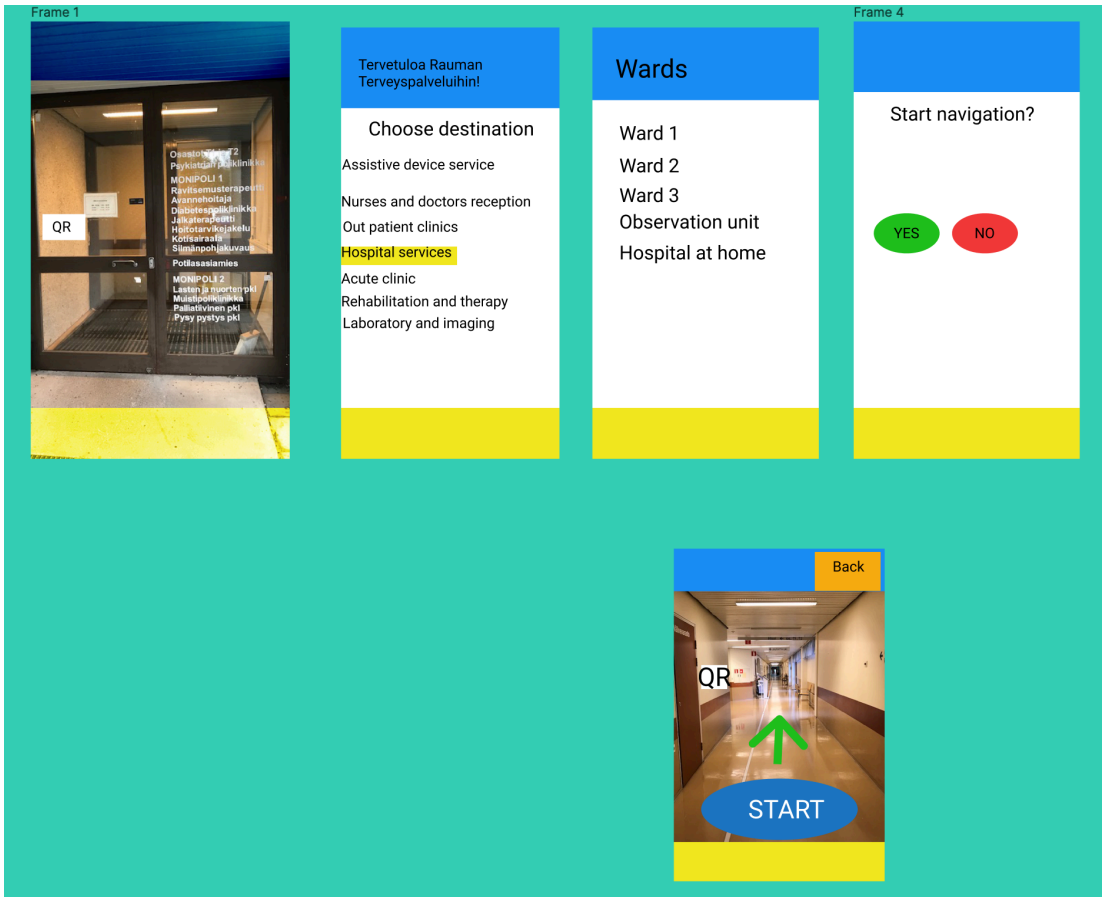
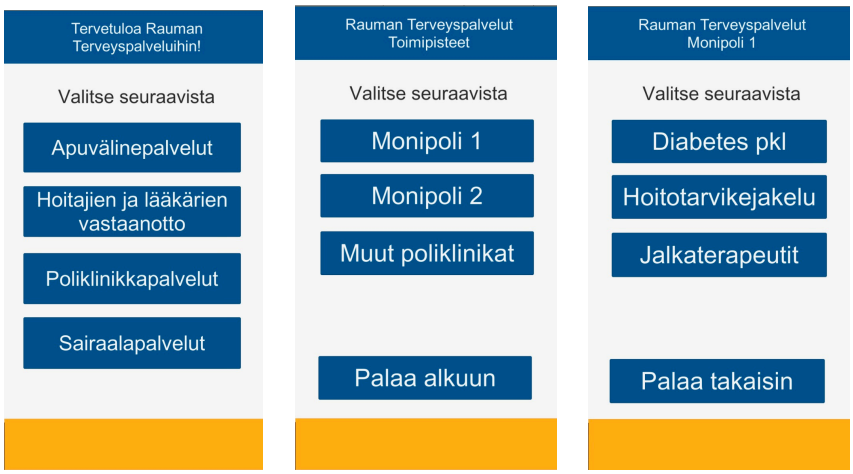


Figure 13. Planning of user interface in the beginning

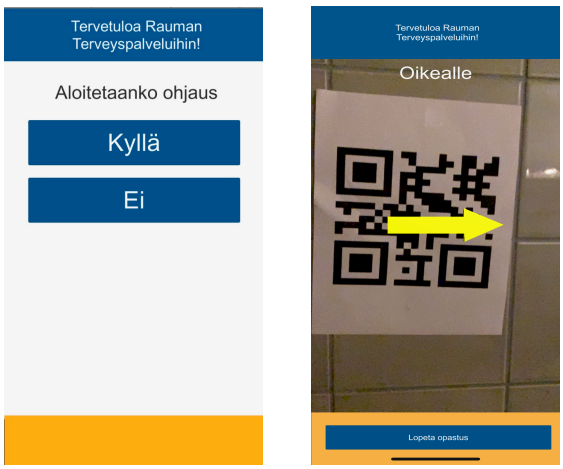
These sketches were shown to programmer at this point to express the idea what is planned. These pictures are early stages of user interface design and part of sensory design level. Sensory level is the surface level and consists elements which enable

interaction. It is set of logical arrangements and seen as visual presentation (Garrett 2011, 134).

Following pictures of user interface are in Finnish, because it is the language the test users speak natively. First frame welcomes to health center of Rauma and instructs to choose from following; Assistive aid services, nurse's and doctor's reception, outpatient clinics or hospital services. In second frame there are outpatient clinics from which you can choose in which you need to be heading. If chosen Monipoli1 like in the second frame, there are options of outpatient clinics which can be found inside Monipoli1 as seen on third frame. Diabetes, care equipment distribution and podiatrists can be chosen from frame three. Frame four asks if the guiding should begin to destination and frame five shows a view through screen.



Frame 1 Frame 2 Frame 3



Frame 4 Frame 5

Figure 14. User interface

Small alterations were made to button object to make it look more pleasant. Bigger alterations were made to information design. Information needed was altered to fit the purpose of testing in natural environment, the healthcare center of Rauma. In the pictures below on left, the choice can be made between Monipoli 1(includes many outpatient clinics), internal medicine outpatient clinic and getting back to the beginning. Monipoli 2 is an example of how other choices could be added even if it was not in use at the moment and marked with gray color. After choosing Monipoli 1 or internal medicine outpatient clinic, the program asks if the guiding should start with signal sounds or voice guidance.

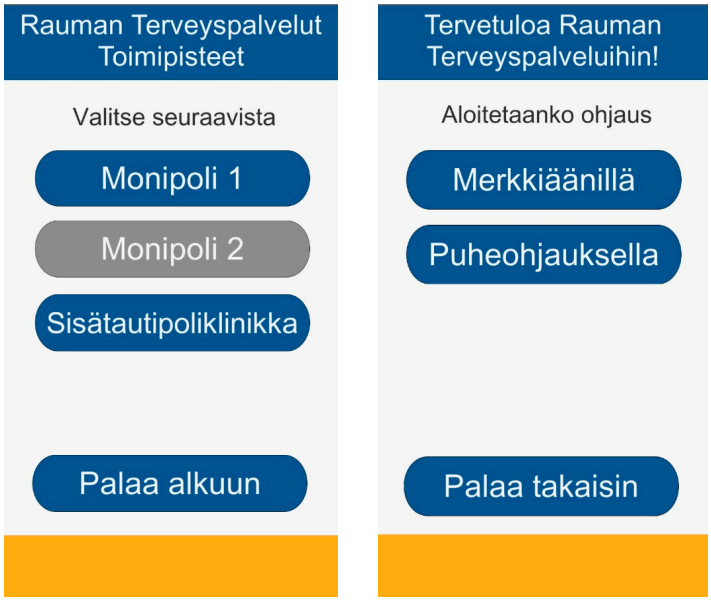


Figure 15. User interface after small alterations

5.3 Technology implementation

The prototype for mobile device was created by ScientialTech programmer. Collaboration with the developer was conducted via GitHub which provides a version control for the project, making the project management easier. Any issues with the development could be issued to the person responsible and issues could be solved and notified such as bugs or wrong button sizes. All issues were listed for future examinations if needed. QR codes, Vuforia AR feature and Unity were combined to create a navigation application. Prototype supports mobile OS versions IOS 12+ and Android 8.1.0+.

5.4 Test plan

The purpose of testing should be clarified before testing is done and plan should be written down. Formative evaluation is done to get information on what details are good and bad and how the interface could be improved (Nielsen 1993, 170).

Testing is going to take place in the healthcare centre of Rauma 29.2-1.3.2020. Side door of healthcare centre was chosen because the area is quieter than the main entrance in the weekend when the testing is going to be conducted. Parking spaces are next to this entrance and considerable number of customers and employees use this entrance daily during weekdays. One test will take about 15 minutes including testing and the interview.

Aim is to test the prototype with people of different ages and different levels of technology knowhow. The aim is also to have the prototype tested with people, who are unfamiliar with the facilities, with people who know the facilities a little and with people who know the facilities well.

After testing the application, interviews are going to be conducted. Nielsen's general heuristics are going to be the guidelines of the interviews. Nielsen's heuristics include making the screen simple and natural, speaking the user's language, being consistent, providing feedback, provide shortcuts for advanced users, using plain language for error messages, prevent errors, make help simple and task-focused (Nielsen 1996, 34). Learnability, efficiency, memorability and subjective satisfaction will be also added to the discussion.

Participants are chosen based on availability and willingness to take part. This kind of sampling might cause significant bias, but as the application is going to be used by people who are willing to use it, this shouldn't be an issue at least in the creation and testing usability of the prototype.

Application needs to be ready enough to test and there needs to be few options to choose from; other choices can be seen but not tested. Testing devices are given to the participants, so they are not required to use their personal smartphones. System response time should not be slow. Criteria for success are when the test person finds the right place, the application allows to stop/resume guiding and if it can be used without instructions. Participants are going to be observed and interviewed. Interface is a success if it is easy to use and it works as was intended. The data is utilized in application development to improve the application.

The testers will be instructed and reminded before testing, that test evaluates the user interface and not the testers. They will be encouraged to speak freely their mind. Test results will be used to improve the user interface, so the system will be somewhat different when released. They will be reminded the testing is confidential and can stop the testing at any point if they wish. They will be encouraged to ask questions and instructions at any point. Thinking out loud is welcomed (Nielsen 1993,188).

6 USABILITY TESTING

Testing with real users is the fundamental usability method and in some sense it cannot be replaced. It provides information directly about what the exact problems are with interface being tested (Nielsen 1993, 165) Right context is vital for gathering people's insights whether it is more expensive or low-cost service. Minimal gap between the expectations and experiences mean greater satisfaction among customers. Observation of participants provides in - depth and accurate knowledge about how people use products and processes. These give a better understanding what people do, rather than what they say they do and what they actually need. Observation should occur in the natural environment and the researcher, by participating, can obtain understanding creating empathy and gain information which can be hard for someone to describe. (Polaine, Lvølie & Reason 2013 p. 45-58) User testing is about testing what you have produced and trying to get rid of usability issues. Prototypes can be used to approach usability issues (Garrett 2011, 47-48).

6.1 Functionality testing

First testing was conducted in 21st of February 2020 with two older adults in their 70s. Purpose was to try out the test procedure and functionalities of the prototype. First three test rounds were conducted in the early stage of the development phase. Devices used in testing were iPhone 5s, iPhone 7 and iPhone 11, Samsung Galaxy Xcover and iPad professional generation 2.

Testrounds were conducted to see if the QR codes could be read with user's own mobile device and if the direction included in the QR code would appear as an arrow. 5 QR codes were placed in the space approximately 3 meters apart and route was planned ahead. Height of QR codes were measured to 140cm from ground up. Aim was to start from the 1st QR code and follow the instructions to the last QR code. Test would be considered a success if testing would follow through all 5 QR codes and finish to point intended. Interviews according to Nielsen's general heuristics were covered after first two test rounds and questions were presented in Finnish as the testers were natively Finnish speaking.

In the first test it became clear the use of AR arrows has to change. If it guided to turn left or right, the arrow should point straight ahead after turning instead of guiding to turn left rest of the way. Also, lighting could disturb the QR code, if there was not enough of it. AR arrow was programmed to stay on sight for 10 seconds and the program could not read next QR code before previous arrow had disappeared. Time it should be seen on screen depends on the distance of QR codes and walking speed of testers. It was decided to reduce the visibility of the arrow to 7 seconds. All in all, the test was a success and good development suggestions were gotten. Haptic feedback was added to give more feedback to the user.

After alterations and improvements were done, it was time for second test round. Time of an arrow present on screen was reduced. There were slight differences between devices and how far away smartphone cameras could read QR codes, but the differences were not significant. Arrow was programmed to give instructions to turn and after few seconds the arrow turns to point straight forward instead of just instructing

to turn. More feedback features were added such as haptic feedback, sounds when pushing the buttons and when finding a new QR code. When finding a way to wanted destination there is longer signal sound. Voice guidance was added so the user can choose the guiding with voice or without. It was noticed that the brightness of the space affects the ability of camera to read the QR codes. QR codes could be read from 2-3 meters of distance. QR codes size was a little smaller than paper size A4 and it was decided to test with smaller QR codes. One of the problems was with the voice guide that if you check the final destinations' QR code twice, it did not repeat the voice instruction. With other QR codes it worked properly.

Third and the last test round was conducted with different lighting conditions and smaller QR code sizes. The size was 7x7cm in the final test. Too dark room effected the cameras ability to see the QR codes and shades were problematic if they were on top of the QR code. Smartphone resumed back to guiding if phone rang in the middle of navigation and continued forward as was intended which was one of the requirements.

6.2 Hospital testing

Testing preparations

Permission was asked from the head nurse of the healthcare centre to use the facilities for testing and to use employees as testers. Permission was also asked for testing the prototype with other people than employees in the facilities from the head nurse. The permissions were granted to both. Aim was to select volunteers with different backgrounds of age and technology using experience. The ages of the participants varied between 12-70. One was in her 70s, one in her late 50s, one in her 30s, one mid 30s and one 12-year-old. The participants had heard little or nothing about the development of this application. For two participants facilities were new and unfamiliar, two had used services a few times. One worked in the facilities and the surroundings were well known. One of the participants had problems with recognizing left from right and anxiety issues. All were familiar with smartphones.

A day before testing, the premises and approximate distances were checked in the testing area. Locations of outpatient clinics were checked because of ongoing changes in the healthcare centre.

Before first testers arrived, 6 QR codes were taped on the left side of the corridor wall, and placed 130cm above ground approximately 15 meters apart. Distance between last QR code and one before that was longer, approximately 20-25m due to the lack of QR codes in numbers. Routes were checked in case there would be some mishaps that could be prevented. Sizes of QR codes were mainly 7x7cm. One 7x7cm QR code could not be read so it was changed to a smaller 6x6cm code which fixed the problem. The lights were on to reduce problems from too dim lighting conditions.

In the beginning all testers were reminded, the interface is being evaluated and not the testers. They were also reminded this is a prototype of the application and their opinions are used to improve the application interface and usability. They were told they can stop the testing whenever they want and to speak their mind freely during testing.

Testing

Testing was scheduled and conducted on leap day 29.2.20 between the hours 9 – 12. It was Saturday and chosen for it is quieter day in that part of the healthcare center, but the facilities are still in use. Testers were instructed to arrive on site 45 minutes apart to ensure the privacy for testing. There were two test routes to choose from and interviews were conducted after testing. Programmer was onsite prepared to make adjustments to the programming of the application if needed. All testers tested at least two routes, with voice guidance and with signal sounds. Testing took 15-30 minutes depending on how much testers wanted to test different options. All of them finished two routes. First route guided to the door of diabetes outpatient clinic and second to internal medicine outpatient clinic. iPhone 7 and 11, Samsung Galaxy J5 and iPad mini 2 were used in testing.

Feedback

All five testers agreed the screen was simple and used language was understandable. Four out of five agreed the information to be consistent and one tester did not understand the question due to young age. All testers felt the application prototype gave

enough and right kind of feedback which included signal sounds, an arrow, haptic feedback, voice or combination of those. All felt the instructions were simple and task focused but there should have been more instructions included, for example an advice to search for QR codes with the camera from the left side of the corridor. All testers felt learning to use the application prototype was easy and the experience was satisfying. The application prototype guided to the point intended and guiding arrow was easy to understand and big enough.

Feedback

- *This was exciting, for once there is something fun at the hospital! The application is perfect the way it is*
- *It felt great!*
- *This is something I would have needed when visiting the hospital last time.*
- *The outlook fits hospital services.*
- *This was fun!*
- *QR codes are placed at regular interval, that is good*
- *It seems the application is doing something important all the time such as looking for QR codes, showing the arrow or making sounds. It gives the feeling of not being lost*
- *There is no possibility of misunderstanding the guidance*
- *The screen was as simple as possible*
- *The experience was nice. If I would have this application and would come here and it guides, I would take it to use. It would be useful in big university hospitals*
- *It works and it´s good*
- *The guidance was good with signals and it was good that arrow showed with voice guidance too*
- *I don't understand these kinds of things easily and I mix left and right, but I got this because it is simple.*
- *Using this application was clear, but if I would have been alone, I would have paid more attention to the application than I did while testing*
- *Yellow color against brownish color was not the best, but the arrow was still clear*

Figure 16. Feedback from testers

When observing testers while they were testing, it became clear not all knew what QR codes are, and what needs to be done after instructing them to follow QR codes. Few testers looked only through the screen of smartphone and it made finding QR codes harder when the perception was focused on small screen. Camera of Samsung galaxy was considerably slower but did not affect the outcome in a negative way. Few testers did not consider instructions seen on screen as instructions and sought confirmation on how to do proceed. Some testers were afraid not understanding what to do before even starting and needed assurance that it is the designers' fault, if the prototype proves to be too difficult to use. A bug was found by the youngest tester concerning the signal.

When reaching internal medicine outpatient clinic, the sound of getting there was missing when it was there for the other destination.

Testers gave opinions of the prototype and suggestions for future development. They were satisfied with the experience using the prototype and participated with enthusiasm. Technology used was completely new to two, three had used Augmented reality applications before.

Improvement suggestion

- *More instructions are needed*
- *When choosing the guidance with signals or voice, there could be signals marking the choice. Voice when choosing voice guidance as an example of the type which is chosen.*
- *Could red arrow be better even if it is a warning color?*
- *What if there were different colors of QR codes if the routes are different? It would be easy to choose right codes to follow"*
- *What if you get lost? There could be instruction what to do if lost and an emphasis on following the QR codes*
- *More contrast in colours to the guiding arrow*
- *Testing with people who do not speak Finnish, could they benefit from this? English version?*

Figure 17. Improvement suggestions

Some testers took notice to traditional signs after trying the guiding application prototype and commented them spontaneously. Only one tester found the internal outpatient clinic sign on top of the door when they had arrived to the destination.

Observations of traditional signs

- *If I would only use traditional signs, I would get lost. There are signs which point at wrong directions.*
- *I did not notice the routes on the floor, there should be a sign for customers to notify them about the routes on the floor*
- *I can only see the red route taped on the floor. Or is it orange. Supposedly there is black and white too.*

Figure 18. Observations of traditional signs

7 CONCLUSION

This project started in autumn 2018 with planning phase. A lot of material was gathered, searched and literature research was conducted in January 2019. In the end of November thesis plan was finished, and it was time to start the actual requirement analysis. Paper prototyping took place in January 2020 and all requirements (Customer, functional, non-functional and design) came together in navigation application prototype in February.

Functionality tests were conducted in mid-February with two testers and 3 actual test rounds. Interviews were conducted two times. Improvements were made to provide more feedback to users and by making the user interface more pleasant by modifying objects on screen. Both testers liked the idea of guiding application.

Usability testing was conducted in healthcare center facilities of Rauma. The application prototype was ready to be tested and offered two different routes to choose from. Five testers gave overall opinions and observations on usability of the application prototype according to interview questions applied from Nielsen's general heuristics user evaluation. Test users were provided with smartphones and a tablet for testing. In their opinion the screen was simple and used language was understandable. Four out of five agreed the information to be consistent and one tester did not understand the question due to young age. All testers felt the application prototype gave enough and right kind of feedback which included signal sounds, an arrow, haptic feedback, voice or combination of those. All felt the instructions were simple and task focused but there should have been more instructions included, for example an advice to search for QR codes with the camera from the left side of the corridor wall. All testers felt learning to use the application prototype was easy and the experience was satisfying. The application prototype guided to the point intended, the guiding arrow was easy to understand and big enough.

Overall there were 7 testers who were excited about the possibility to use AR guiding application. Tested devices were iPhone 5s, 7 and 11. Samsung Galaxy J5, iPad mini 2 and iPad pro Generation 2 were tested in the process. Prototype supports mobile OS

versions IOS 12+ and Android 8.1.0+. Service performance of the application can be described as success based on the testers describing the application as positive experience even if more instructions were wished for in the future. Error messages were not included at this stage of development which lessens the success a little bit. The system response time was fast even if there were slight differences when using different mobile devices. All testers found the places intended. Smartphone resumed back to guiding if phone rang in the middle of navigation and continued forward as was intended. The interface was a success. It was easy to use and worked as intended.

A lot was learned during the making of this requirement analysis. Gathering of particular information and documentation took time even if it seems there is not a whole lot of information gathered. If this project was done again, I would gather the testers to one workshop to discuss improvement proposals. It would possible be more fruitful than interviewing them separately. Participative observation gave information on how people use the application in the natural environment and what challenges they face that cannot be predicted when designing a prototype. Examples of these could be looking only through screen narrowing the field of vision or how to instruct people to aim for QR codes.

Based on improvement suggestions, more instructions are needed, such as an instruction to follow QR codes and instruction of what to do if gotten lost. As to noticing the instructions on screen, bigger font size and different color of instructions might fix the problem. More contrast needs to be added to colors and suggestion were given which colors could be better. One of the problems with the surroundings was, it was partially green and white and other part brown, yellow and white. Automatic scaling of colors could help with this problem. English version was suggested to enable the use for people who do not speak Finnish. A suggestion to use different colors of QR codes was great even if the use of it would be problematic in one surrounding because the QR codes hold information for many routes and not just one. The colored QR codes could possibly be used in the hospital surroundings which has many different buildings and colors could be utilized to mark different buildings.

As what comes to timing of this project, due to many factors, the timetable of the project had to be thought through from the beginning. Changes at the healthcare center made information gathering more time consuming but still manageable.

8 DISCUSSION

The timing could have been better. Technologies are arriving to hospital services, but the focus is more or less in the reformation of healthcare on a municipal level. During the time this project was conducted, the hospital of Rauma has changed to healthcare center, although many services have remained. At times it was difficult to remember what was being created, a prototype or full application. It affected the designing process.

The costs to create this application remained in the paper to print QR codes on, because the development work could be done free of charge. The actual use of finished product is liable to charge in form of license fees for different platforms. There has to be some expenses considered if alterations have to be made to the application such as if the clinics or wards move from one place to another or if the names change. The use of this kind of application should be free of charge to the customers.

One of the guidelines of Finnish government is to provide smart information systems for the personnel which support the processes. This application would be good support service for main services, following the guidelines of digitalization 2025. This project will continue under the development of ScientialTech software house.

8.1 Ethical consideration

The testers of the application were volunteers and were informed of what the application is for and reminded they can stop testing whenever they want. They were chosen based on their technology knowledge, their familiarity with the facilities and they represent different age groups between 12-70.

Discussions started in 2018 with head nurse of healthcare center and by the end there were discussion had with two head nurses concerning this project. There was no need for research permission other than the permission which was acquired from the head nurse to test the application in the healthcare facilities of Rauma.

Making of this prototype is not revealed on technical level, for it is something that will serve the productization of this prototype in the future. The potential for this technology is valuable for healthcare services because of its potential in guiding and potential in future development.

Created application does not gather information about the users ensuring their privacy. It does not film or have option to take pictures. Group of people who do not have smartphones are not able to use this application or those who have bad eyesight or much degraded motor skills. On the other hand, the employees could possibly serve these customer groups better with more time in their hands if some other user groups would use this navigation application.

Many of the risks and recommendations of VR (Virtual reality) technology can be also applied to AR (Augmented Reality) technology. Human brain can be strongly influenced by external influences while not being aware of this influence. The environment, including technology and other humans, has unconscious influence on our behavior. VR introduces the new kind of cognitive and cultural environment. For experiments on VR/AR, it should follow the principle of maleficence: Do no harm, to get the informed consent from those involved in the experiment, the application should not give false hope and to recognize the beneficence and autonomy conflict (Emadary & Metzinger 2016).

8.2 Development suggestion for the future

In the future, it would be interesting to conduct a customer survey at Rauma health care centre to see, if there would be interest using this kind application.

More information and locations could be added to the application keeping in mind the simplicity and usability. Interface could include the number of QR code “stops” lined up, so the person using the application, would see how long way it is to the wanted destination. There could be other 3D images added, perhaps a coffee cup in front of café and what not, to make the application more appealing and approachable.

QR codes could include the opening hours of clinics, information/guidelines of getting ready for blood tests and other instructions for customers. There could be instructions for employees such as phone numbers of clinics only available for other professionals or instructions page in case of hospital bacteria outbreaks. These instructions would be only available for staff.

The possibilities are numerous. To use this affordable choice as a navigation option is only up to the developers and healthcare centres/hospitals to take the next step and start using the technology which is already here.

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Applied Nielsen's general heuristics, Interview questions for the testers

- 1. Is the screen simple? – Onko näyttö yksinkertainen?
- 2. Is the used language understandable? – Onko käytetty kieli ymmärrettävää?
- 3. Is the information consistent? – Onko tieto johdonmukaista?
- 4. Does it provide feedback? Antaako ohjelma palautetta?
- 5. Are instructions simple and task focused? Onko ohjeet yksinkertaisia ja tehtäväkohtaisia?
- 6. Is it easy to learn? – Oliko helppo oppia käyttämään?
- 7. Was the experience satisfying? Oliko kokemus miellyttävä?
- Ja muita kysymyksiä
- 8. Did it guide to the point intended? – Opastiko valittuun pisteeseen?
- 9. Were the guiding arrow easy to understand? – Oliko opastava nuoli helposti ymmärrettävissä?
- 10. Ideas, suggestions – Ideoita, ehdotuksia?

Figure 19. Applied Nielsen's general heuristics interview questions