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# **CO-DESIGNING VIRTUAL REALITY PRODUCTS**

## **CASE STUDY AT DIGIA FINLAND OY**

Faculty of Information Technology and Communication Sciences  
Master's Thesis  
April 2019

# ABSTRACT

Olli Havilehto: CO-DESIGNING VIRTUAL REALITY PRODUCTS  
Master's Thesis  
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This thesis validates the use of co-design as a part of virtual reality product development projects. The research focuses on co-designing and prototyping in an organizational setting and the research was carried out as an action design research.

The problem was that the case company had no prior commercial experience from virtual reality market and the competitors had already entered the industry. We introduced the basic virtual reality application possibilities for the employees and formed a robust method for iterating through the different application ideas which arose from the participants.

Product prototypes were implemented with Unity software framework and tested with Oculus Go goggles. The prototype applications were designed for two internal departments: e-commerce and IT service center.

Involving the employees in the co-design process turned out to be a fruitful and positive experience. Prototypes received a good reception and may cause further ventures.

This research does not take a stance on whether research company should or should not enter virtual reality industry but provides experience and a solid basis for further dialogue. Also based on this research it is safe to assume that there is internal interest for both virtual- and augmented reality applications.

Both co-design and prototyping also worked well as parts of virtual reality product development projects. These methods helped the participants to visualize their thoughts and concretize their goals.

*“When you are used to look at the world through flat screens it can take a while to be able to understand what you can achieve with the flat screen content when it is released from the restraints of physical borders.” -Interviewee.*

The principal of this thesis is Digia Finland Oy, precisely Digia Digital -department.

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Olli Havilehto

Keywords: Virtual reality, Co-design, Product prototyping, Software design, Unity

## Vocabulary

ADB, Android Debug Bridge

ADR, action design research

AR, augmented reality

ERP, enterprise resource planning system

IDE, integrated development environment

IT, information technology

IT-artefact, concrete result of development such as computer program or project plan

Scene, Unity game world

VR, virtual reality

Web, world wide web, the Internet

Webview, Embedded Web page or element

Web-api, Application programming interface for Web protocols

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## 1 Introduction

Product design and development consists of multiple aspects. In this research we examine co-design and prototyping as methods for designing products in a real environment where a company may be on a verge of entering a new industry: virtual reality. The scientific question is *how does co-design fit virtual reality product development project and how does it perform while introducing a whole new industry for the employees.*

Chapter 2 describes the scientific background of our research: co-design and prototyping. Co-design is an attempt to facilitate users, researchers and other stakeholders in a creative co-operation, so they can explore and envision ideas, develop and test sketches and experiment with prototypes. In co-design the participants are the ‘experts of their own experiences’ and through a facilitation this knowledge is utilized for experimenting with a novel technology or a putative opportunity. [Tiainen et al. 2012; Steen et al. 2011]

Prototyping was selected as a method as it ensures that the product development fulfils the defined design goals [Youmans 2011]. Prototyping may also take the development beyond the requirements and introduce the best, optimal solutions [Arnowitz et al. 2007, 3]. Prototyping may also ease the communication between design and development [Nelson et al. 2016].

Chapter 3 introduces us to our case company. The concrete problem was that competitors of the case company had already seen and acted on the opportunity of virtual reality and the case company was yet to make its move. [Accenture 2019; CGI 2019; Tieto 2019] The case company wanted to test, trial and gain experience of virtual reality application development as it may offer possibility for extra sales and income for expert organizations by e.g. offering value for their customers. [Jung and Dieck 2017; Sherman et al. 2009]

Co-design and prototyping were carried out as parts of action design research (ADR) which is described in chapter 4. ADR included a series of interviews, prototype development and co-design workshops. ADR provides an iterative model for the research which allows the refinement of application requirements and features throughout the development process before the final IT-artefact is formed. The interviews, observations and employee feedback were used to steer the development into right direction.

Theory and practice were merged into a development model which is described in detail in chapter 5. We first introduced the basic virtual reality application possibilities for the employees and created a robust method for iterating through the different application ideas which arose from the participants.

As a result, application prototypes were formed. These prototypes and gained knowledge are meant to act as a stepping stones for entering to the new industry and complementing the research company’s IT service catalogue with virtual reality. The prototyping process itself may also be regarded as a valuable experience for the company considering the future ventures. This all was achieved by utilizing the knowledge and competence of the employees and robust scientific methods in the design process.

## 2 Scientific background

User participation in the design process has become a norm and possesses a long tradition [Tiainen et al. 2012; Steen et al. 2011; Ehn 1988]. Users can provide the designers with domain knowledge in several ways during the different phases of the development e.g. kick-off (user interviews), development (user design and testing) and retrospective (user feedback). Designers can apply this information to their design knowledge to efficiently solve the design problems. [Olsson, 2004].

In this research we observe co-design and prototyping as methods to participate the users in the design process. Co-design benefits our process by enabling wider range of people to contribute in the formulation of the solutions [Steen et al. 2011]. Prototyping was selected as a method because it allows us to evaluate different ideas and, if necessary, adjust the scope according to the feedback [Arnowitz et al. 2007, 3].

We also introduce similar (to this) studies from Mencarini et al. [2018], Alhumaidan et al. [2017], Peacock et al. [2017], Nelson et al. [2016], French and Teal [2015], Tiainen et al. [2014] and Steen et al. [2011]. These studies and study findings provide the verified basis for our own co-design and prototyping workshop model.

### 2.1 Co-design

Co-design allows a team to combine two sets of knowledge which are important for product design: *customer insights* into user needs and in-house expert's conversion of *promising ideas* into viable concepts. [Trischler et al. 2017].

Co-design is described as an attempt to facilitate users, researchers and other stakeholders in a creative co-operation, so they can explore and envision ideas, develop and test sketches and experiment with prototypes. It allows wider range of contributors to participate in a service design. Co-design can also be used to facilitate different challenges almost regardless of the industry. Immediate benefits of co-design include but do not limit to: [Steen et al. 2011]:

- Better ideas with higher user value
- Better knowledge of customer needs
- Immediate validation of ideas
- Lower development costs
- Shorter development times
- Higher customer satisfaction

Co-design differs from participatory design (Table 1) by having different starting point: in participatory design a designer can invite a group of people who currently work together and can keep their current practices (*what is*) whereas in co-design one can invite people who have never met before and start with an idea for novel technology or putative opportunity. [Tiainen et al. 2012]. Compared to co-creation the co-design offers a more in-depth approach: co-creation can be any act of collective creativity which is shared by two or more people.

Co-operation focuses on:	Designers move towards users	Users move towards designers
Concern for <i>what could be</i>	Co-creation	Co-design
	Contextual design	Lead user approach
Concern for <i>what is</i>	Ethnography	Participatory design

Table 1. Different human-centred design approaches with different starting points and emphases [Tiainen et al. 2012; Steen et al. 2011].

French and Teal [2015] utilised co-design in a design-led project where they designed a new digital application for Scottish Ambulance Service. In their analysis they state that co-design sessions (Figure 1) led to identification of multiple key requirements such as required information, application navigation and screen design and application functionalities and infrastructure. French and Teal also held a role-playing session (Figure 1) where participants displayed their working practices in a realistic scenario. This allowed the designers to identify and shape the requirements of the IT-artefact accordingly.



Figure 1. Role playing session and co-design workshop. [French and Teal 2015, 448, Figure 1.]

Co-design sessions allowed the participants to design and trial with the key requirements and implementations and discuss their observations. Discussions revealed a consensus for optimal application design and properties. Similar findings may be observed from studies of Mencarini et al. [2018], Alhumaidan et al. [2017], Peacock et al. [2017] and Steen et al. [2011] which are introduced below.

Mencarini et al. [2018] developed a wearable device for rock climbing with co-design. They wanted to learn if climbers would use wearable devices and for what purpose and which design attributes the devices should include to be accepted by the climbers. The process was split into five studies, each answering into a different sub-question:

1. Understanding the climbers' attitude towards wearable devices
2. Exploring the opportunities of wearable devices in climbing (Figure 2)
3. Exploring vibrotactile wearables for augmented communication (Figure 3)
4. Designing and implementing a vibrotactile prototype
5. Evaluating a vibrotactile prototype

Mencarini et al. [2018] state that co-design was crucial for eliciting the many aspects which are involved in sports such as culture, practice and experience and to orchestrate them with the cultural and physical aspects of wearing an artefact.



Figure 2. Showing climbing gear, working in pairs and drawing concepts. [Mencarini et al. 2018, 34, Fig. 3.]

User-centered design with participatory and situated design practices along with co-design allowed them to start mapping design space of acceptable, desirable and useful wearable devices for sports [Mencarini et al. 2018].



Figure 3. Contextual co-design workshop: the climbing session. [Mencarini et al. 2018, 35, Fig. 4.]

Alhumaidan et al. [2017] performed a similar co-design process with children to design a collaborative augmented reality book based on a primary school textbook. They noted that children were surprisingly interactive during co-design sessions and stated that the argument of children being natural partners for co-design is extremely supported. They recommend having a specific set of protocols for all the participants to follow in order to control the design sessions and amount of gathered data. Similar positive results regarding co-design with children were reported in a study by Steen et al. [2011].

Steen et al. [2011] also describe how they managed to improve customer satisfaction and quality of the service by utilising co-design with employees to improve an existing logistic service. These positive attributes and traits are also desirable for our research; hence use of co-design for facilitating the design process is considered justified and sufficient.

Peacock et al. [2017] utilized co-design workshops and prototyping to design a home energy management system. They found that user-centered design approach offered a way for creating a conversation regarding energy which was meaningful and promoted response among the participants. Their designs not only were radically different to the norm but also yielded sustained user engagement over a six-month screening period.

## 2.2 Prototyping

Prototype is an early version of an artefact which stands as a basis for later stages and development. [Yang 2005; Arnowitz et al. 2007, 3]. Prototyping is the process of creating and shaping the prototypes.

Prototyping is often used for product or service design to ensure that the results meet their requirements. Prototyping may also help to save resources such as time and effort because instead of just describing the requirements it helps to visualize them. When prototyping is done right it also allows to go beyond the requirements and explore for the best, most optimal solutions. [Arnowitz et al. 2007, 3]

### 2.2.1 Prototype fidelity

Prototypes can be categorized per level of realism or *prototype fidelity*. These categories may be referred to as low, medium and high: *lo-fi*, *mid-fi* and *hi-fi* (Figure 4). Building of the prototypes is a trade-off between time, resources and fidelity. Designers should aim to develop lowest and cheapest possible prototypes which still are effective. This means that the prototype can be built quickly and inexpensively but it still is able to provide required information. [Yang 2005].



Figure 4. Prototypes of a floor scrubber: A) high fidelity, B) medium fidelity and C) low fidelity. [Sauer et al. 2009, 135.]

Low-fi prototypes are fast, easy and cheap way for prototyping ideas. Low-fi prototypes may consist of paper, post-it notes, cardboard etc. Advantage of low-fi prototypes are the low cost and low bar for involving non-professionals in the prototyping process. Hi-fi prototypes are closer to the final product and cost more resources such as time and money to implement. Physical hi-fi prototypes also reduce design fixation. [Egger 2000; Youmans 2010]. Both types may be used through the prototyping process.

Tiainen et al. [2014] found that low-fi prototypes generate more development ideas from the participants compared to hi-fi prototypes. Tiainen et al. also present that virtual prototypes with accurate and detailed images may be placed between low fidelity and high fidelity as semi-hi-fi.

### 2.2.2 Prototype types

Prototypes may be divided into two types: *physical* and *virtual* prototypes. The chosen type may affect things such as design fixation, cost, development time and the users' ability to interact with the prototype. [Youmans 2010; Tiainen et al. 2014]. Tiainen et al. [2014] state that the users understand and can evaluate the virtual prototypes similarly to physical ones which may encourage to use cheaper and faster virtual prototypes. Virtual and physical prototypes do not exclude each other and may be used together during a design process.

Tiainen et al. [2014] studied virtual and physical prototypes and consumers' reactions to both in a furniture expo setting. Customers could observe both physical and virtual prototypes without touching (Figure 5). Touching was not permitted due to the researchers guiding the users to compare the prototypes by available, equivalent features.

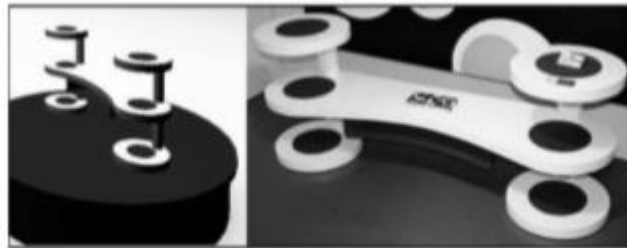


Figure 5. Virtual and physical prototypes of a TV shelf. [Tiainen et al. 2014, 6.]

Physical products were high fidelity hand-crafted prototypes with same features as the ready products have. Virtual products were semi-high-fidelity prototypes: 3D images of the products presented to the users in actual size. Virtual prototypes also had realistic materials and similar functions as the physical counterparts. [Tiainen et al. 2014]

Tiainen et al. [2014] found out that the users, furniture expo guests, evaluated the product properties of virtual and physical prototypes similarly. Users focused on product materials, dimensions, design and quality. Users did not complain about the missing opportunity of touching.

Most remarkable difference between the prototypes was regarding development ideas and feedback: virtual prototypes created a lot of more development conversation and ideas compared to physical ones. One reason could be that virtual prototypes may give the observer a feeling or sense of a still ongoing development process. Thereby the research suggests that consumers see virtual and physical prototypes similarly but focus more on development with virtual prototypes.

### 2.2.3 Software prototypes

Software prototyping is an important part of a software product development. Software prototyping answers to questions like [Arnowitz et al. 2007, 10]:

- Will the designed features work properly?
- Can the designed features be implemented economically?
- How the customers will respond to the design?
- What approaches can we take when turning the design into a product?

When developing a product these questions are important both technologically and economically [Arnowitz et al. 2007, 10-11].

Software prototyping process itself consists of multiple steps. Nelson et al. [2016] describe an iterative prototyping process model (Figure 6) where they refined user requirements for a health information exchange dashboard. Their objective was to describe the design of a dashboard and the refinement of user requirements through rapid prototyping.

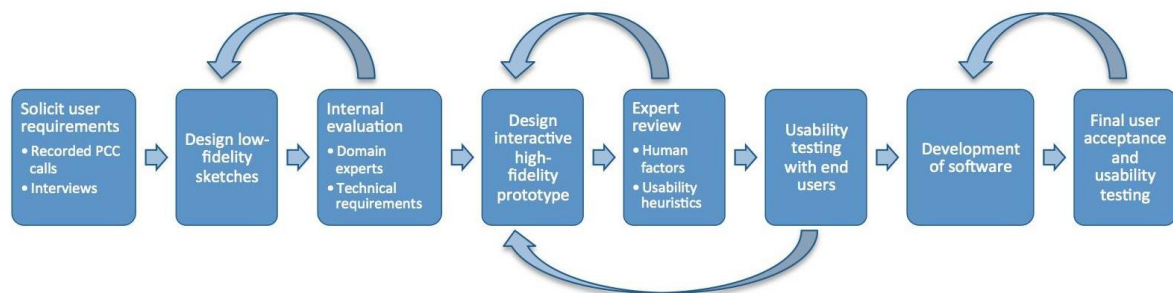


Figure 6. Iterative development model. [Nelson et al. 2016, 28. Fig 1.]

First Nelson et al. [2016] utilized existing user requirements which they used to design low-fidelity sketches with pen and paper (Figure 7). These low-fi prototypes acted as a basis for further development and allowed the stakeholders to participate in the design process.

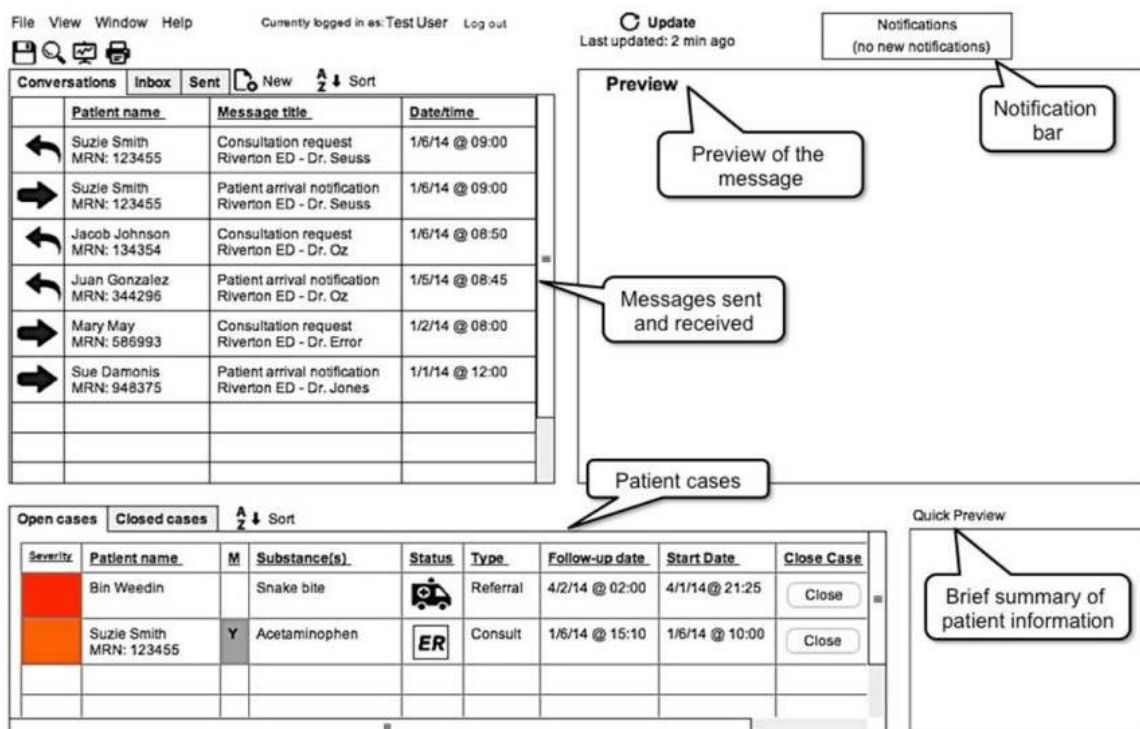


Figure 7. Refined version of low-fi prototype. [Nelson et al. 2016, 28. Figure 1D.]

After developing and refining the low-fi prototypes with participants they developed an interactive hi-fi prototype (Figure 8) and conducted scenario-based usability tests with end users. After the testing, users provided feedback and evaluated the prototype using System Usability Scale. [Nelson et al. 2016]

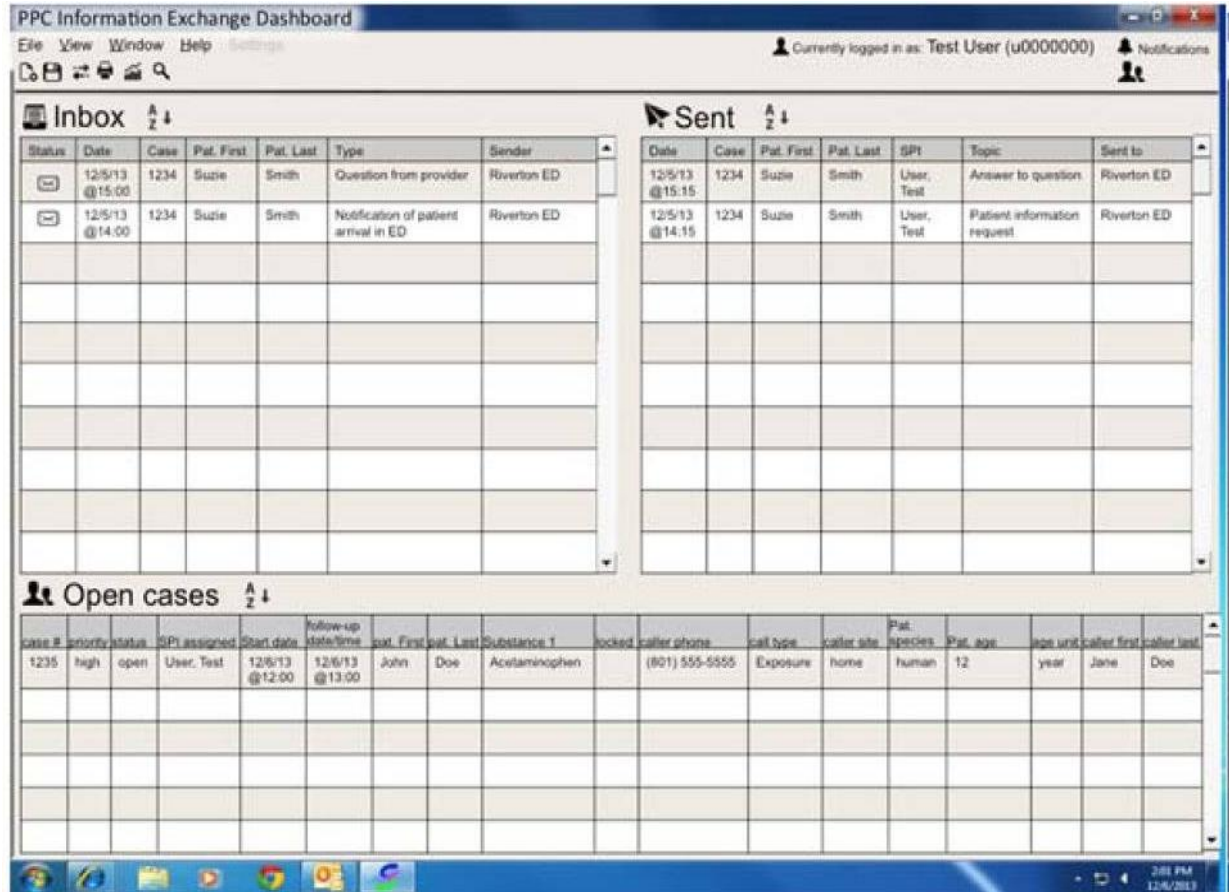


Figure 8. Refined version of low-fi prototype. [Nelson et al. 2016, 29. Figure 1A.]

User contribution provided useful feedback which was incorporated into the design. After achieving a stable design, they used the prototype itself as the specification for the development of the actual application.

They list the benefits of prototyping as [Nelson et al. 2016]:

- Subject-matter experts were heavily involved with the design.
- Flexibility to make rapid changes.
- Ability to minimize software development efforts in the early stage.
- Rapid finalization of requirements.
- Early visualization of designs.
- Powerful tool for communicating the design to the programmers.

Nelson et al. [2016] also list challenges:

- Prototyping and case scenarios require resources such as time and effort.
- No simulation of system performance.
- High cohesion to systems with unfit or lacking data.

From the point of view of our research these selected scientific methods conclude a list of good and desirable traits for the research. With co-design we can combine customer insights with their needs, convert in-house expert knowledge into viable concepts, immediately validate ideas, lower the cost of development, shorten the development time, achieve higher customer satisfaction and higher user engagement.

Prototyping ensures that our requirements are met while saving time and resources, enables going beyond the requirements during development and seek for optimal solutions, eases the communication between design and development, minimizes unnecessary efforts during the early stages of development and gives us flexibility to adjusting to rapid changes.

### **3 Case company: Digia Finland Oy**

Digia Finland Oy, later only Digia, is an IT service company that helps its customers harness digital opportunities. Digia has over 1000 employees and Digias' annual turnover was 112,1 million euros in 2018. Digia is a publicly listed company: DIGIA at Nasdaq Helsinki Ltd. [Digia Company Description 2019; Digia Investor relations 2019]

Digia was a good case company for the research since in addition to software consulting Digia offers its own products and possesses prior prototyping experience. [Digia OTE 2019; Digia MES 2019; Digia Tempus 2019; Digia ProDiary 2019] Virtual reality as a concept was also seen as an interesting topic for the both company and researcher.

The researcher of this research acts as a full-stack web developer in Digia Finland Oy. In the science world he is studying for a master's degree in computer science.

#### **3.1 Company preview**

Digia's service catalogue consists of four different service areas:

- digital services
- industry solutions
- information management services
- financial sector

These service areas serve different industries like telecom, insurance, banking, logistics, public sector and so forth. [Digia Company Description 2019] In this research we focus on digital services area; Digia Digital department.

#### **3.2 Problem**

Digia's service catalogue does not include virtual reality services. Commercial virtual reality solutions have raised their head within the customers [Leonidas case Valmet 2019]. Other large software consultancy actors like Accenture, CGI and Tieto already offer virtual reality for their customers. [Accenture 2019; CGI 2019; Tieto 2019]

These example companies have also been listed as the main competitors for Digia by Inderes Oy [Grönqvist ja Rautanen 2018]. Inderes is the largest Finnish equity analyst company. [Inderes company description 2019]. Also, smaller consultancies like Leonidas Oy offer virtual reality services for large industrial actors like Valmet Oy [Leonidas virtual reality 2019; Leonidas case Valmet 2019].

We had to briefly introduce virtual reality as a concept for the employees and to come up with a robust method for testing and developing different virtual reality application ideas which arose from the stakeholders. The development results and development process itself would be the basis of further discussions regarding the new industry in the case company: virtual reality.

#### **3.3 Technology**

As a large software consultancy Digia possesses knowledge and knowhow from many different tools, frameworks and programming languages. Researcher decided to use Unity

3D engine and Oculus hardware due Unity being a familiar and widely used framework and the company already possessed two Oculus Go goggles which were purchased for employee entertainment purposes. Oculus also offers seamless integration and libraries for Unity development.

Though the virtual reality as a concept was a new industry for Digia, in this case its technologies and programming language were familiar for the company: Unity supports C# programming language and Unity IDE comes with a Visual Studio integration.

Some of the Digia Digital employees also had earlier development experience with Unity 3D engine which was not related to virtual reality.

### 3.3.1 Unity 3D

Unity is a game engine developed by Unity Technologies. Unity was first released in June 2005. Unity may be used to create 2D, 3D, virtual and augmented reality games and applications. Latest version of Unity, 2018.3, has been released December 2018. [Unity Company Description 2019]

Unity applications compile for 25+ different platforms and 60 percent of world's AR/VR content is made with Unity [Unity Company Description 2019; Unity Public Relations, 2019].

### 3.3.2 Oculus

Oculus VR is an American technology company founded in July 2012. Oculus VR launched a Kickstarter fundraiser campaign in August 2012 to make virtual reality headsets available for developers. Campaign raised 10 times its original target goal, 250,000 dollars. Oculus VR released two developer versions of the goggles (DK1, DK2). Oculus was obtained by Facebook in March 2014 for US\$2.3 billion in cash and stock and the first consumer device, Oculus Rift, was released in March 2016.

Oculus Go is the descendant of Oculus Rift and the entry-level model of the Oculus VR goggle family and comes with a one simplified wireless controller. Oculus Go goggles cost 219 euros and are powered by ARM architecture with Snapdragon 821 CPU. Goggles presented in Figure 9. [Oculus Go 2019; Oculus Go Review 2019] Oculus Go operating system is based on Android 7.0 [Oculus Go Android, 2019].



Figure 9. Oculus Go [Oculus Hardware, 2019.]

## 4 Method of research

For this research ADR was chosen due to the need of developing IT artefacts in an organizational setting. ADR aims to develop and evaluate a concrete IT artefact according to the organizational requirements whereas design research (DR) focuses more on the technological implementation itself [Sein et al. 2011].

As a practical development project this research allowed us to test how co-design and prototyping behave as a part of a virtual reality product development project and how our observations relate to previous studies. For the science audience this research verifies the use of co-design, prototyping and interviews in an organizational-setting product development project. Our main question is:

- *How does co-design fit virtual reality product development project and how does it perform while introducing a whole new industry for the employees?*

Which is complemented by additional questions:

- *How does co-design engage the research company employees?*
- *How does the prototyping combine with co-design?*
- *How does the prototyping fit virtual reality development?*

### 4.1 Action design research

ADR aims to develop and evaluate an IT artefact. It combines practices from action- and design researches. ADR describes four phases (Figure 10) for artefact design process which are guided by predefined principles.

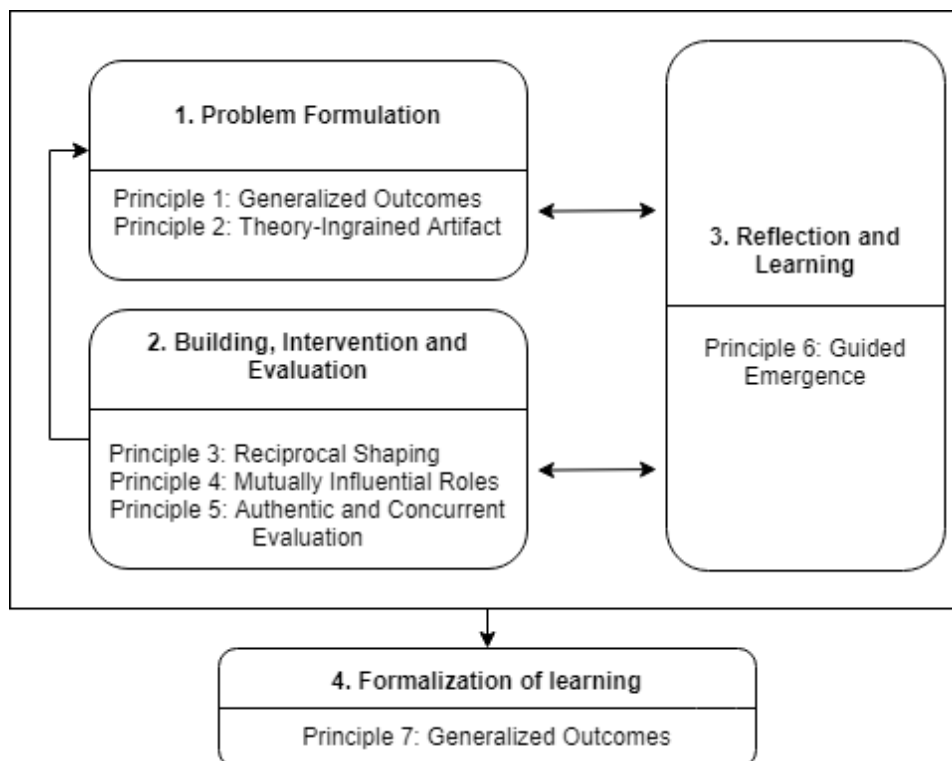


Figure 10. ADR and phases. [Sein et al. 2011, 41.]

In this research the IT artefacts were the two virtual reality prototypes and related observations for future ventures. The artefacts were developed in parallel, but the different businesses only participated in the design of their respected artefact.

#### 4.1.1 Problem formulation

In the first phase of the research we formulated the research efforts. Input for the formulation may come from different stakeholders: practitioners, end-users, researchers, technologies and prior research data. [Sein et al. 2011]

Problem formulation answers to questions [Sein et al. 2011]:

- Initial size of the scope
- Research roles
- Stakeholders
- Scope and amount of practitioner participation
- Initial research questions

This stage identifies and concretizes the research opportunity based on the existing theories and technologies. It should be noted that after this point the participating organizations should be well committed to the research project. [Sein et al. 2011]

The problem was that the case company had no prior commercial experience from virtual reality. We had to come up with a robust way for testing and evaluating virtual reality concepts with the employees.

Stakeholders of the research were:

- Researcher
- Employees of Digia Digital
- Executives of Digia Digital

The interviewed employees presented both practitioners and end-users. Executives of Digia Digital observed the research from the background. Researcher was responsible for daily tasks and research work, employees committed to perform multiple iterations of product prototyping and executives provided funding and tools.

The initial scope of the research was to:

- Gain experience from virtual reality through prototyping.
- Base the prototype designs and specifications on organisational requirements.
- Participate the employees in the design process and take advantage of the employee knowledge and experience.
- Provide the organisation with recommendations and thoughts regarding future development in virtual reality industry.

#### 4.1.2 Building, intervention and evaluation

Second phase consists of building and evaluation of the product as described in the Figure 11 [Sein et al. 2011].

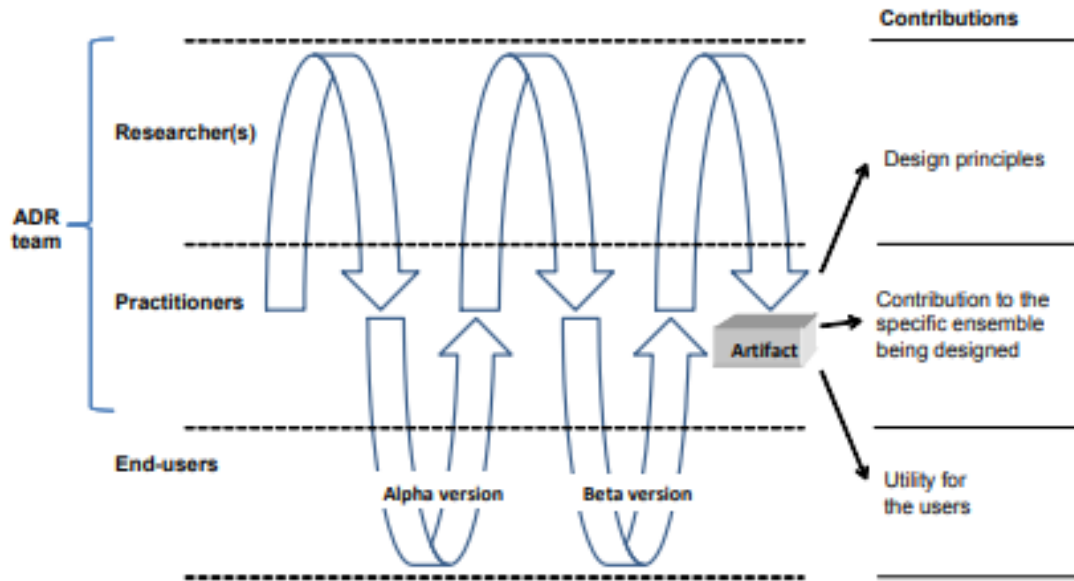


Figure 11. The Generic Schema for organisational-dominant BIE. [Sein et al. 2011, 43.]

BIE (building, intervention and evaluation) is an iterative cycle which combines the development of the artefact, organization intervention and result evaluation. End-product of the cycle is a concrete IT artefact. [Sein et al. 2011]

Tasks of the BIE-cycle are [Sein et al. 2011]:

- Discover initial knowledge-creation target
- Select or customize BIE form
- Execute BIE cycle(s)
- Assess need for additional cycles, repeat

In this research *organizational-dominant BIE* was chosen over *IT-dominant BIE* because *organizational-dominant* approach emphasizes organizational intervention as the primary source for innovation whereas *IT-dominant* focuses more on creating a technology based innovative designs [Sein et al. 2011].

Organizational dominant approach was easy choice since we were acting in an organizational setting and we were developing application ideas and prototypes with and for the employees and their customers.

Amount of iterations differed between the participated businesses but the basic structure for the second phase is described in Figure 12.

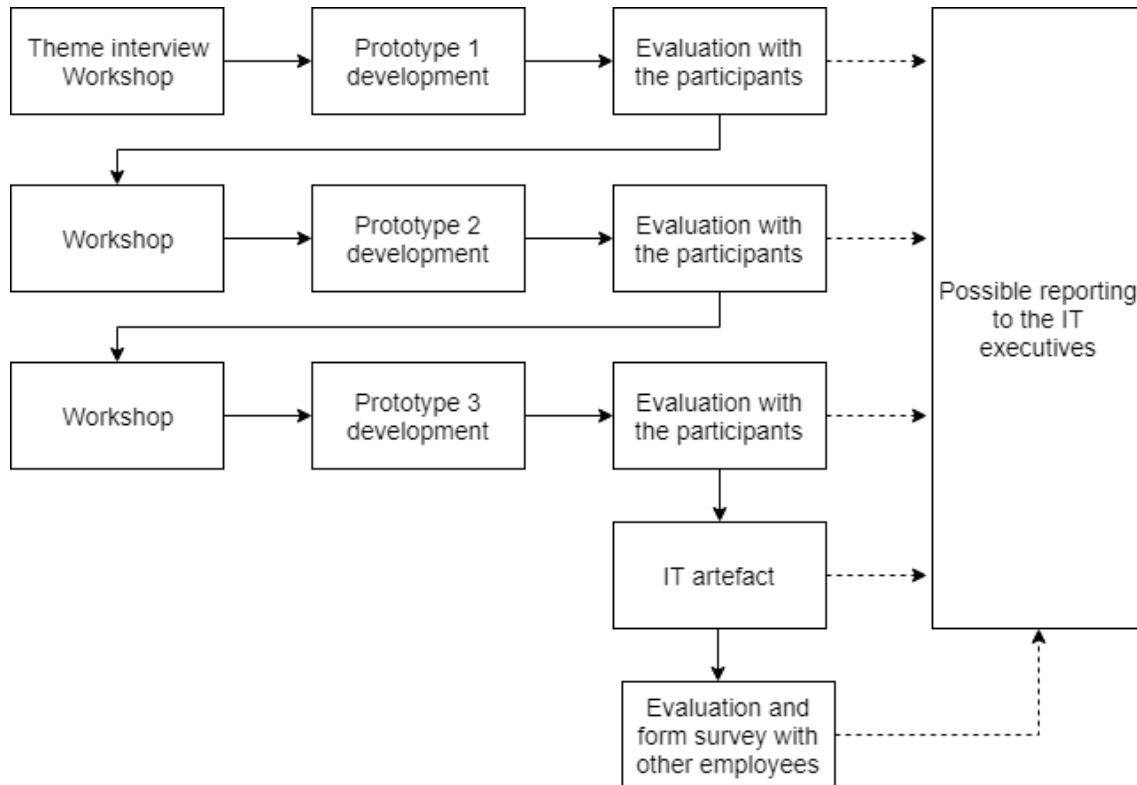


Figure 12. Organizational-dominant BIE-cycle of the research.

Two prototypes were developed in a parallel with parallel BIEs and the first iterations were started with a theme interviews and a workshop where initial prototype properties were defined. It was followed by a prototype development which usually took about couple weeks to complete. After the development, prototype quality and properties were reviewed and refined by the practitioners who participated in planning through the interviews and workshops. These iterative BIE-cycles were repeated multiple times. IT executives of Digia Digital were kept up to date about the development regularly but not punctually after every cycle.

As a result, two IT artefacts were formed. After the development phase these artefacts were tested by larger audience in a shared session consisting of case company employees also outside of Digia Digital. The testers filled a form survey regarding general thoughts and possible interest to see virtual reality and application prototyping in their respected area of business.

#### 4.1.3 Reflection and learning

Third phase of ADR raises our scope from actual building of the artefacts to applying our learnings to a broader class of problems. This is a continuous phase and parallels to the first two phases. Research process should also be adjusted based on early evaluation results to reflect the increasing understanding of the ensemble artefact. [Sein et al. 2011]

Tasks of the third stage may be listed as [Sein et al. 2011]:

- Reflect on the design and redesign during the project
- Evaluate adherence to principles
- Analyse intervention results according to stated goals

Reflection of the problem framing and chosen theories with the emerging ensemble are critical for ensuring that the contributions for knowledge are properly identified. [Sein et al. 2011].

This phase draws on principle: *guided emergence* which means that the result artefact is not just an embodiment of the initial research plan but also shaped by organizational participation: point of views, perceptions, participations and parallel evaluation. [Sein et al. 2011]

Reflection and was were done after every iteration. This helped us to adjust our ways of working and the scopes of the prototypes.

#### 4.1.4 Formalization of learning

Fourth and last phase of ADR is formalization of the learnings. This allows us to develop general solution concepts for related problems. [Sein et al. 2011]

Steps for the formalization are [Sein et al. 2011]:

- Abstract the learning into concepts for a class of field problems
- Share outcomes and assessment with practitioners
- Articulate outcomes as design principles
- Articulate learning considering theories selected
- Formalize results for dissemination

Formalization of our learning is concluded in chapter 6: Discussion.

## 4.2 Informants and interviews

Informants of this research were mainly the employees of the case company. Informants consisted of project manager, transition manager, team lead and IT service desk specialist. Some additional data was collected from external meetings. For example, *Finland Unity User Group* meeting turned out to be fruitful regarding learning of production challenges and real-life situations with virtual reality applications (Figure 13).

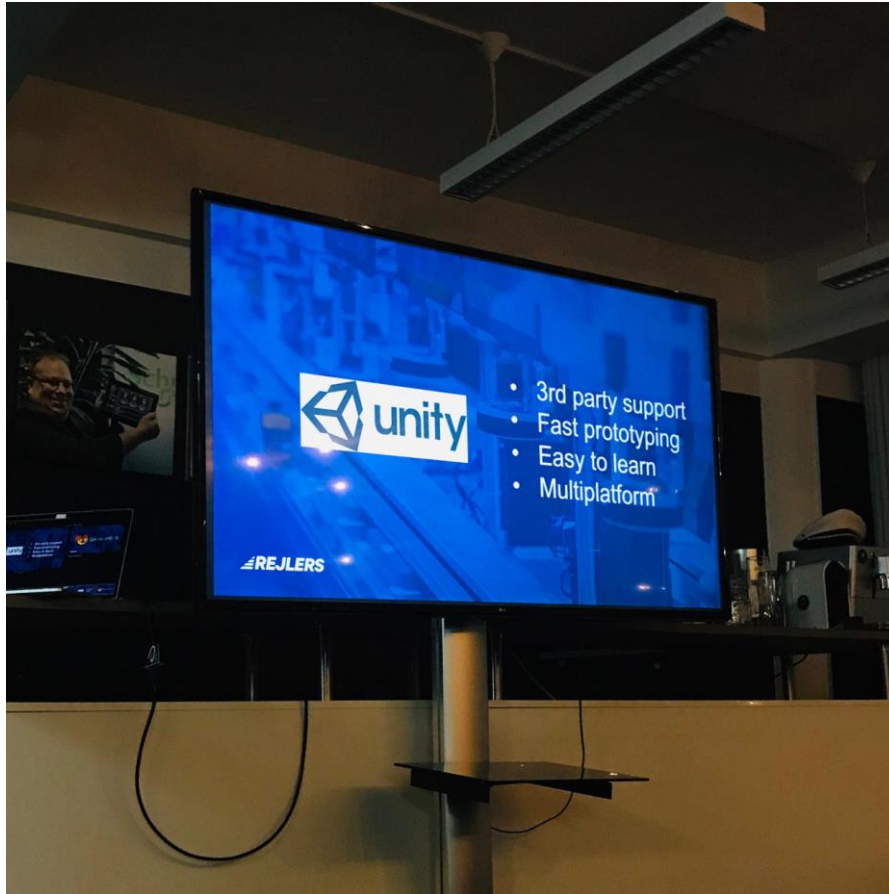


Figure 13. Unity being recommended for VR/AR applications at local Finnish Unity User Group meeting at Leonidas Oy 16.1.2019, picture by Olli Havilehto

Interviews in a computer science research can be split into three categories: *theme interviews*, *form interviews* and *open interviews*. Theme interview follows the themes defined by the researcher. Form interview has a detailed structure which is followed strictly. Open interview is the most flexible option but requires a lot of work during the analysis. [Tiainen 2014]

Actual customers of Digia were not involved in the research. This was due to the strict schedule and the nature of very early prototyping. Possible needs of the customers were addressed through managers and employees with up-to-date understanding of customer businesses. Interviewing multiple employees also allowed us to do triangulation which means using multiple sources of information to ensure the validity of the collected data [Tiainen 2014].

#### 4.2.1 Theme interviews

In this research the theme interviews were mainly used for two purposes: to find out possible interest regarding virtual reality and to gain understanding and a further dialogue about what the different businesses and their end-users might possibly want to prototype. This helped to adjust the requirements of the prototyping process and the properties of the prototype applications.

Interview themes were:

- Employee and employee organization.
  - Current job description.
  - Length of career.
  - Organizational requirements, possibilities and restrictions regarding VR.
- Prototyping and previous product development experience.
  - Prior knowledge and understanding.
- Technology.
  - Knowledge and thoughts.
  - Previous experiences.

These themes also allowed us to learn who our interviewees were, where do they place in the organization and how long careers they had. This gave us an arguing ground regarding if the interviewees had enough experience to analyse what their customers might need.

Interviewees were selected rather randomly since the first business representatives who were invited were all interested in the research. Hence the invitation process was rather quick and streamlined. Official invitations for interviews were sent by email for persons who indicated interest towards the research verbally.

#### 4.2.2 Form survey

Form survey was held after the prototypes were ready and finished. Different employees and organizational actors got to test all prototypes and say what they thought about virtual reality as a concept and if and how they would like to proceed with virtual reality prototyping in their business domain. Survey questions and answer can be found from attachments (attachment 1.).

## 5 VR Prototype research process

This chapter describes our prototyping and co-design workshop model. The model was based on introduced scientific background. Prototyping process was started by gathering field notes regarding general employee interest towards virtual reality solutions in Digia and virtual reality solution features. Two internal business departments were invited as prototyping participants and two employees per business were invited for theme interviews and co-design workshops.

Interview themes allowed us to learn who our interviewees were, where do they place in the organization and how long careers they had. This gave us an arguing ground regarding if the interviewees had enough experience to analyse what their businesses or customers might need.

Co-design workshops provided the basis for our prototype design process. Framework for the workshops was adapted from Mencarini et al. [2018] and French and Teal [2015]. The workshops were held in a case company meeting room which was dedicated to act as a virtual reality laboratory (VR-Lab). (Figure 14).



Figure 14. Ongoing co-design workshop in the VR-Lab.

Objectives of the co-design workshops were to define, sketch and evaluate prototypes and prototype properties similar to Sauer et al. [2009]. These workshops were held the start of BIE-cycles. Defined and sketched prototype properties formed a specification for the further development (Figure 15).

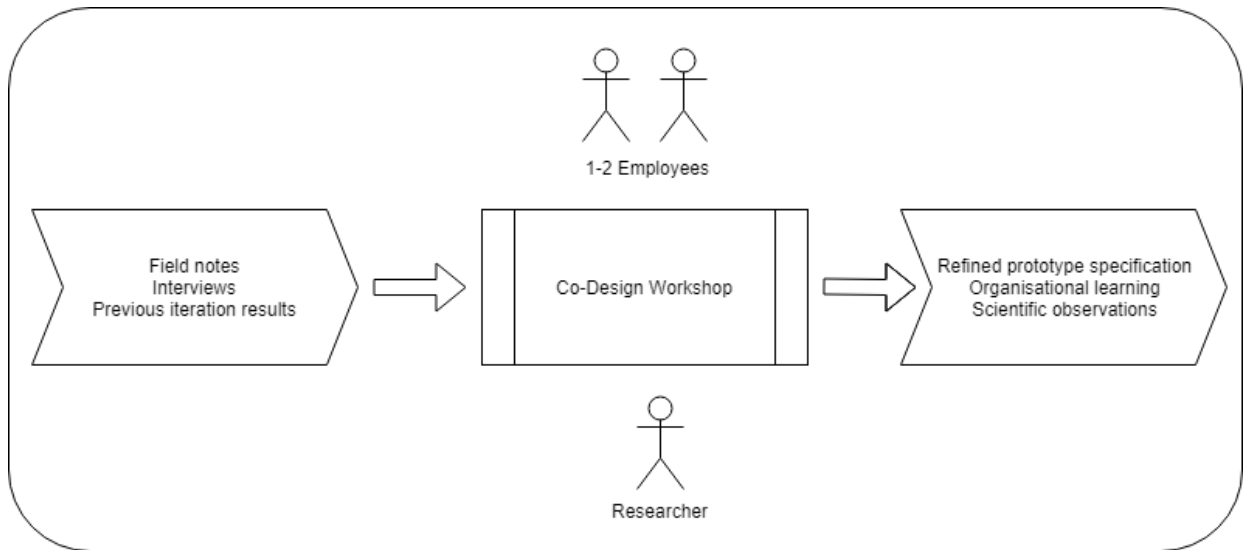


Figure 15. Co-Design Workshop with input attributes and output contributions.

Software prototype features were altered or implemented later during the BIE-cycle according to the specification and low-fi prototypes formed in the workshops (Figure 16). Iteration results acted as a basis for the next development cycle.

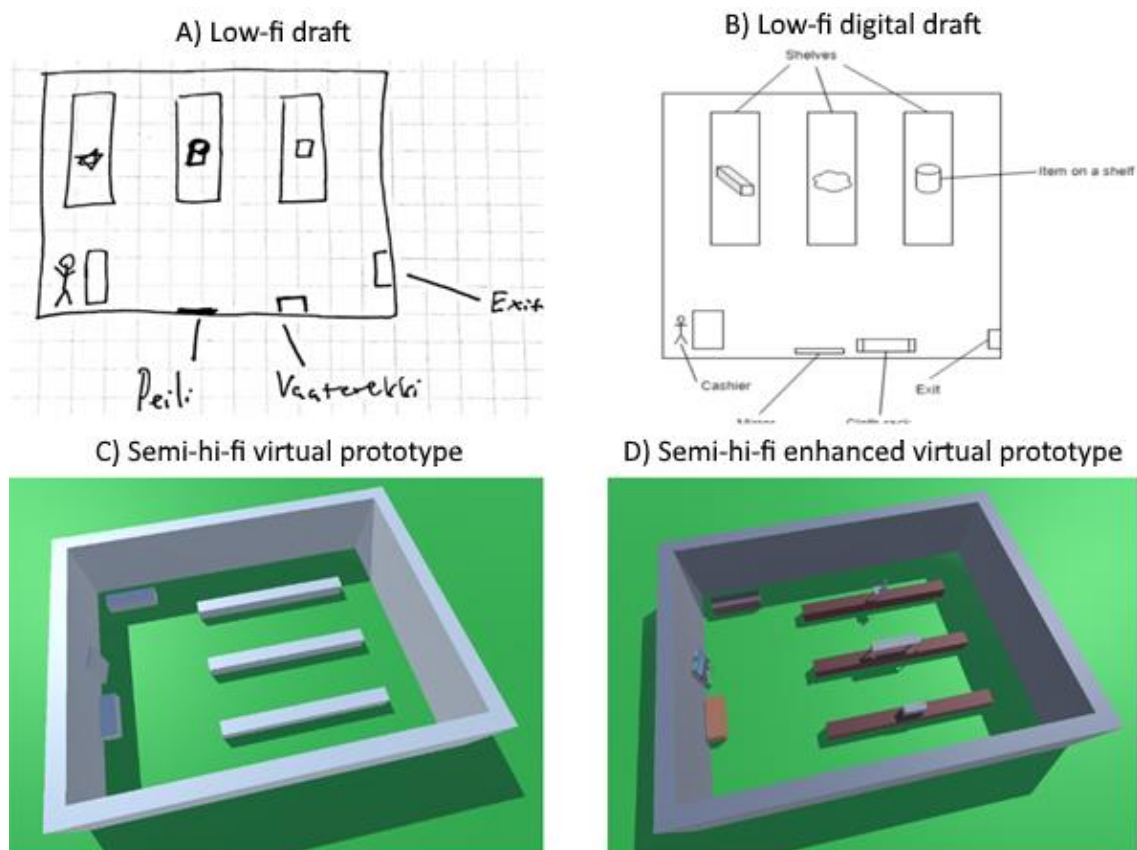


Figure 16. Early e-commerce application prototype evolution. A) Low-fi draft, B) Low-fi digital draft, C) Semi-hi-fi virtual prototype, D) Semi-hi-fi enhanced virtual prototype.

## 5.1 Prototype 1: Digia Verona

Before actual prototyping with participating businesses, a test application, *Digia Verona*, was developed. Development of Verona did not follow presented research process as the application properties were only defined by early field notes and it was partially developed for learning purposes.

Businesses or other stakeholders did not participate in the development of the first prototype, but the field notes were considered as possible features for the actual business application prototypes. Digia Verona was used during initial co-design workshops to build vision of our technical possibilities for the participants.

Digia Verona included a set of 3D-models. These models were developed with Blender. Song and sounds of the application were made with Apple GarageBand [Blender 2019; GarageBand 2019].

Digia Verona features (Figure 17):

- 3D-model rendering within the virtual world
- API communication and data fetching
- Data visualization
- Player movement and interaction
- Object lifting and movement
- Playing music through an object

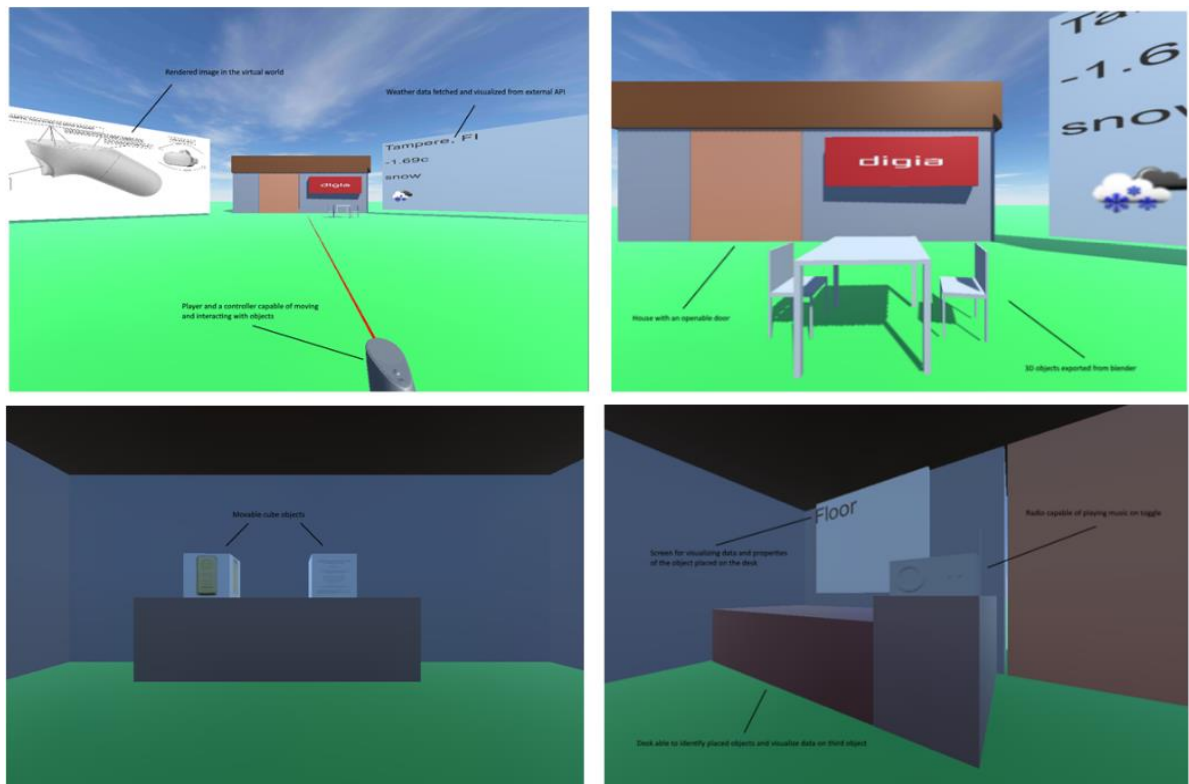


Figure 17. Digia Verona.

## 5.2 Prototype 2: Virtual Walk-In Web Store

First participating business was e-commerce department of Digia. Development team consisted of two e-commerce employees and the researcher. Digia offers many different e-com platforms and services. These include for example Magento, EPiServer and Drupal. In addition to platform and application development Digia offers e-com application upkeep, customer experience personalisation, product information management and integration. [Magento 2019; EPiServer 2019; Drupal 2019; Digia E-Commerce 2019]

### 5.2.1 First iteration

First iteration was started with two separate workshop and interview sessions which contributed for the development of same prototype. Interviewees were acting as project manager and team lead in e-com department. First interviewee, the project manager, had been in the current position for a year. Previous four years she had been a part of internal e-commerce product development and delivery team as a software developer. Second interviewee, the team leader, had been employed at the case company for year and a half. She had prior product development experience of two years from a previous company.

During the first session, virtual reality as a concept raised an active conversation and the interviewee had previous experience from entertainment VR applications and appliances. Prototype-wise the virtual reality discussion and ideas circled around virtual walk-in stores where users can view, compare and purchase items in a virtual environment. Interviewee addressed benefits of the virtual walk-in stores to be:

- “Wow” -effect.
- Ability to browse and compare physical items virtually from anywhere.
- New channel for sales and income.

After some discussion a virtual reality walk-in store was selected as the prototype application theme.

First workshop was complemented by a second interview and workshop. Second interviewee brought up somewhat similar features and prototype requirements as the first interviewee. The most significant addition was the idea of adding a “virtual dressing room” where users could test on different kind of clothes and view themselves through a nearby mirror. Interviewee stated that this kind of functionality might interest multiple different retail customers of the case company.

Properties and features defined for the first prototype were listed as (Figure 16 B):

- Large room.
  - Long shelves.
  - Items on shelves.
- Ability to inspect extra information from an item on the shelf.
- Ability to search an item using search field, visualization of the item location on a shelf.
- Ability to add item into a shopping cart.
- Ability to interact with a cashier.

- Ability to try on clothes.
- Ability to view clothes on the player through a mirror.

It was also addressed that nobody really wants to stand in a queue in a virtual reality store just like they do not want to do in a physical retail store. This means that while going for the wow-effect we should not replicate the “annoying” elements of traditional stores such as standing in the queue but instead focus on developing features which add extra value for the end users.

After the workshops, the development was ready to start. First the low-fi drafts were turned into a digital, virtual form. After rough layout and positioning of the walls, shelves and other elements, the virtual environment was coloured and filled with items (Figure 19).

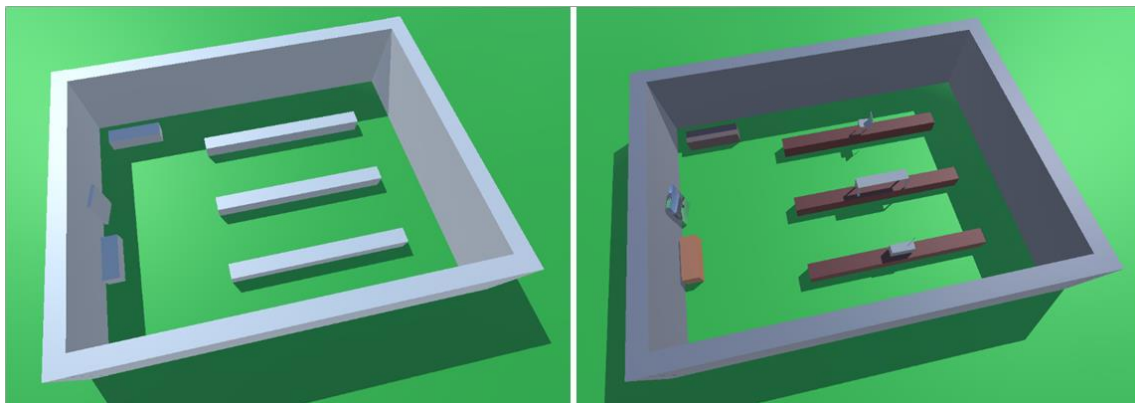


Figure 19. Coloured virtual environment with items.

As the requirement specification also included a support for adding items to the shopping cart, a simple Node.js RESTful web-api was implemented. For now, the web-api was very simple and only briefly mimicked a proper shopping cart solution. Pointing an item and pulling the trigger of the wireless controller triggered a http request to the web-api which attempted to add an item to the cart.

During the first iteration the following features were implemented (Figure 20):

- Ability to walk in a store environment
- Ability to look into a mirror
- Ability to observe simple items on desks
- Ability to add an item into the shopping cart by pointing and clicking on it

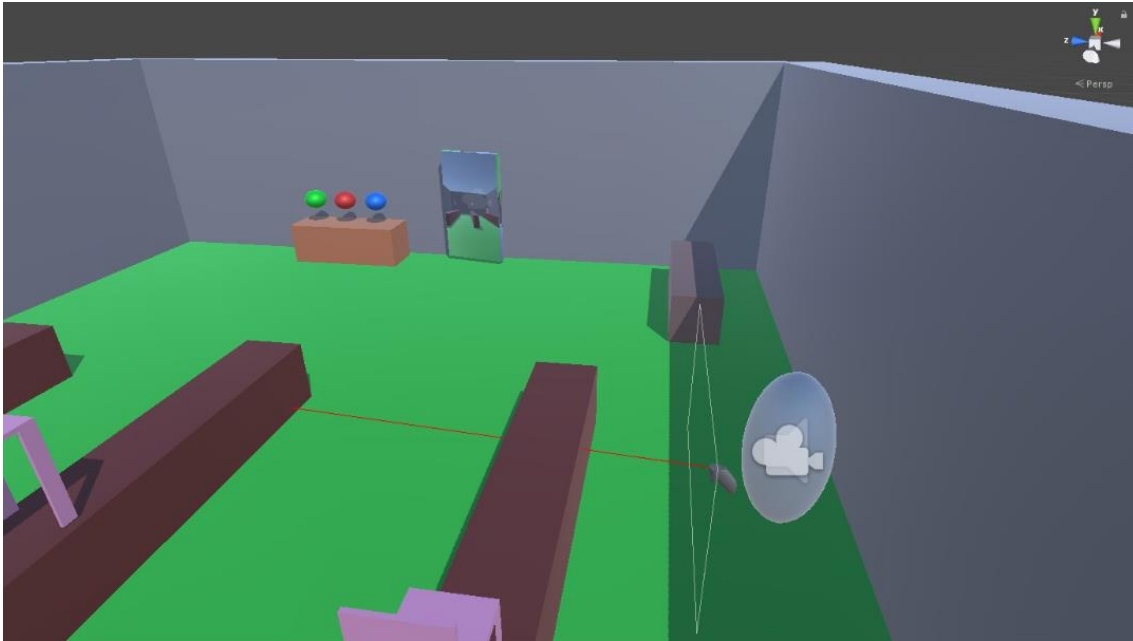


Figure 20. Virtual store with player, items and mirror.

Support for cashier was not implemented yet as it was unnecessary or incomplete function: it would have required significant development but might have only added limited depth and immersion for the application. Search field was also left out as there were only three items in the store so searching was unnecessary function. Player also possessed a placeholder model of a simple orb.

### 5.2.2 Second iteration

Second iteration was started with a single workshop where both participants attended. First iteration results were presented for the participants and it acted as a basis for the upcoming design work. Participants were pleased with the results and the direction of the development. Attributes for the second version of the application were defined as:

- Natural colour for the shop items.
- Make the player model more human-like.
- Add an exit for the room.
- Consider adding more realistic clothes.
- Consider adding support for submitting an actual shop order.

During the development the mirror and cloth -functionalities were moved into another room and Unity scene (Figure 21). This turned the prototype into more modular form and gave us an opportunity to only ship the "fitting room" functionality as a separate application if required. Player also now had a more human-like model with realistic clothes but without a support for changing the outfit yet.



Figure 21. Fitting room.

Player was able to move between the rooms by using a fitting room door. Player was also able to exit the prototype by interacting with the exit door. Items were also given more natural colouring (Figure 22). Order submission and API communications were not implemented during the iteration due to limited schedule.



Figure 22. Shop items with natural colouring.

### 5.2.3 Third iteration

Third iteration was also started by a design workshop with the participants. It was decided together that API communications and shopping cart submission would be left out of this prototype and postponed for later as it did not deal with the core theme of the prototype: virtual reality.

Features for the third iteration of the prototype were defined as:

- Add a roof for the shop.
- Add textures for the rooms.
- Add lights.

During the development it was noted that how easy it is to create lights and shadows with Unity framework. Also, floors, walls and the roof were provided with a high-resolution textures which really improved the immersion of the environment. (Fig. 23-24.).



Figure 23. Enhanced virtual store with lightning and textures.

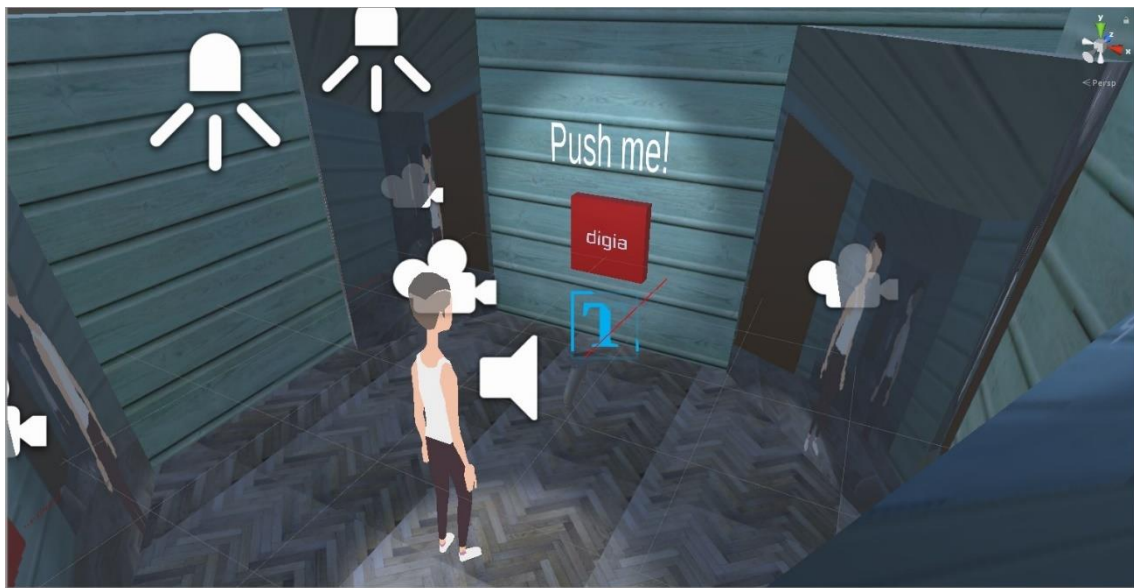


Figure 24. Enhanced fitting room with lightning and textures.

At the end the IT artefact consisted of two rooms (Figure 25) and multiple functions. User could walk around the store, interact with the items, add the items into the simple shopping cart, enter the fitting room, change the colour of player's shirt, observe the outfit through mirrors and walk out from the store.

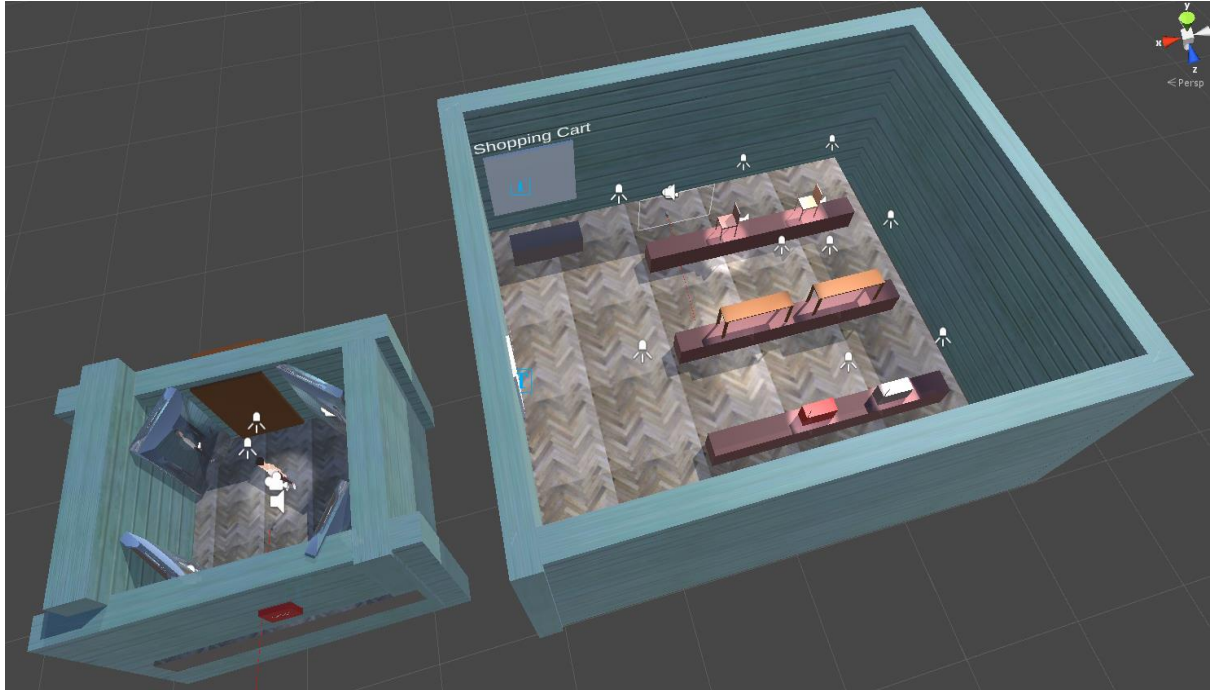


Figure 25. Final layout of the virtual web store and fitting room.

Development was halted after the third iteration. Prototypes were developed under a tight schedule and participants were pleased with the results. Participants also felt that their collaboration through co-design was fun and enhanced their commitment for the project. They would also like to try co-design in other projects.

Participants were also asked to describe the immersion of the application. The virtual world was a rather immersive, but the experience was limited by a low resolution of the virtual goggles. Textures and lightning were felt as really important factors regarding the immersion. The fact that the textures had placeholder-like appearance did not hinder the experience.

The prototype could be developed further by adding more textures for the fitting room, improving the shopping cart function and investigating a method for 3D-scanning realistic item models into the world. After these features the application usability could be tested in a role-playing session similar to French and Teal [2015].

### 5.3 Prototype 3: Virtual Control Room

Second participating business was internal IT Service Center of Digia. Development team consisted of two IT Service Center employees and the researcher. IT Service Center is Digia Finland's internal IT department which acts as a sole point of contact for external and in-house customers regarding daily IT appliances and infrastructure.

### 5.3.1 First iteration

First iteration was also started with separate theme interview and workshop sessions which contributed for the development of same prototype. First interviewee was acting as a transition manager in CSO office but had tight ties and long history with IT Service Center. He had been in the current position for 8 months and in the previous but very similar position for two to three years. Totally he had been employed at Digia for 11 years. He had no prior experience from prototyping or product development. Second interviewee was acting as a system specialist in the first-line it-support of the IT Service Center. He had been employed at Digia for 2,5 years and possessed no prior product development experience.

First interviewee had not used virtual reality applications or appliances but could name different virtual reality appliance vendors such as Google and Oculus. Interviewee also stated that: *“as an old hypermedia student I’ve got a clue what virtual reality could possible offer to us.”*

Second interviewee was a virtual reality enthusiast with personal experience from many different virtual reality platforms and devices. He was interested in virtual reality development both for entertainment and commercial industry purposes.

During the first session with the transition manager the conversation regarding virtual reality applications for IT Service Center steered the design quickly towards virtual control rooms. He presented examples such as Finavia and Valtion Rautatiet, big national logistic actors, which have, according to the interviewee, large physical control rooms consisting of countless displays and status data of different services. [Finavia 2019; Valtion Rautatiet 2019]

Interviewee pointed out that such large control rooms cost a lot of money to maintain and virtual implementation of such rooms could be useful e.g. from the economical point of view. Other benefits could be ability to understand the current service situations with *“one gaze”* due to the possibility of presenting larger amount of data at once.

This kind of product could be both utilized internally in Digia and sold as a service for external customers. Virtual reality control room was also selected as the prototype application theme.

Second interviewee was also interested in developing the virtual observation room -prototype which was first started with the first interviewee. After some thinking he stated that *“when you are used to look at the world through flat screens it can take a while to be able to understand what you can achieve with the flat screen content when it is released from the restrains of physical borders”*.

Interviewee also noted that in the future virtual control room application could also just complement and extend regular workstation work. This could be achieved by using virtual reality glasses with cameras and *“see-through”* -functionality.

Properties and features defined for the first prototype were (Figure 26):

- Four information screens which can be moved and interacted with.
- User has stationary position being unable to move but can turn.

- API communication and test data fetching for the screens.
- Ability create, remove and modify the virtual screens dynamically.
- Ability to stretch the views into 360 panoramas.
- Ability to connect the keyboard into the prototype application in addition to the wireless controller.

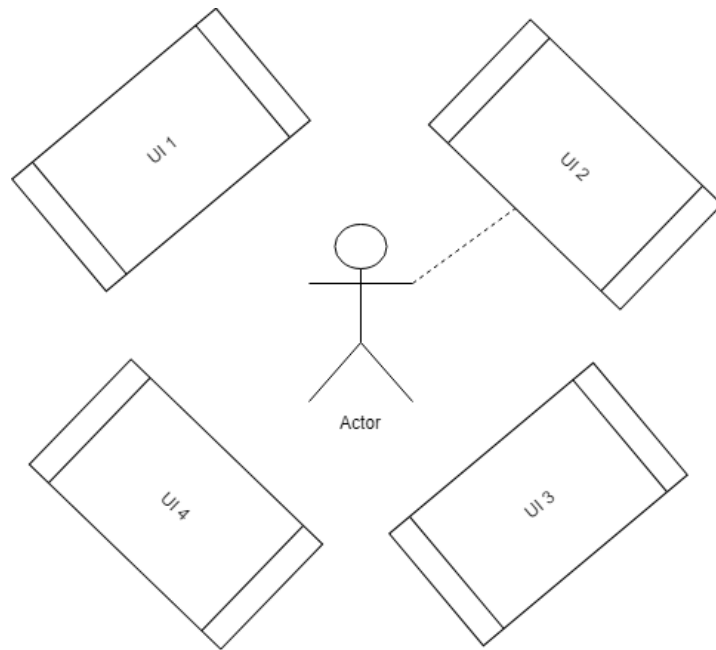


Figure 26. Low-fi draft of a virtual observation room.

Development was started by adding the specified information screens and player model for the observation room (Figure 27). Player was unable to move but could turn around in the environment. Prototype was also integrated into the same HTTP API which was developed for the e-commerce. API was enhanced with additional restful services which served this prototype. Data visualization was not implemented due to the strict schedule.

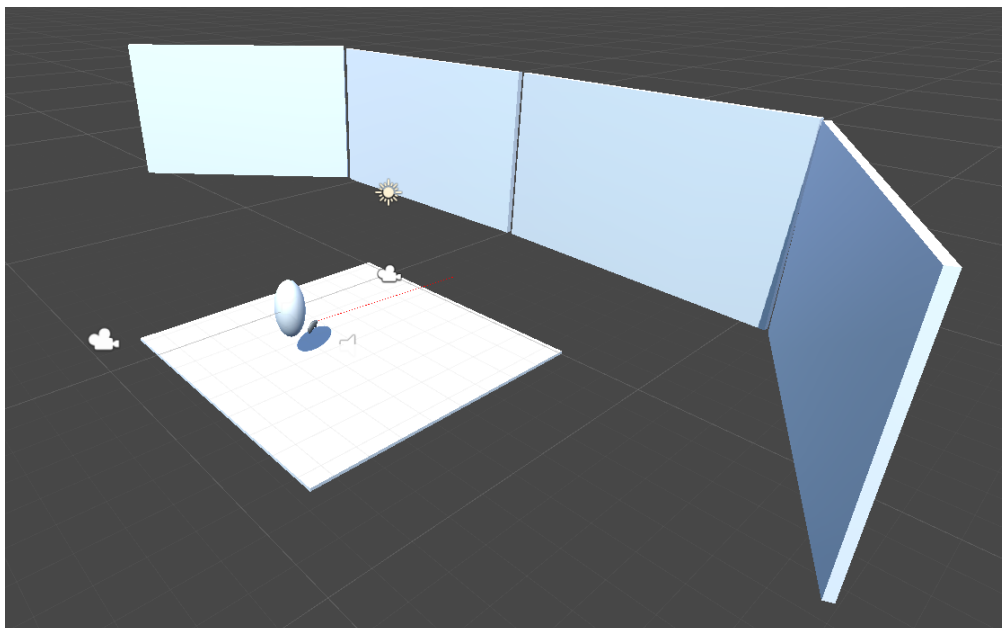


Figure 27. First draft of virtual information screens.

During the first iteration the following features were implemented:

- Ability view blank information screens.
- Ability to rotate the player in the room.

### 5.3.2 Second iteration

Second iteration was started with a shared workshop with both participants. Participants were satisfied with the direction of the development though the system specialist pointed out that the demo is still closer to a technology demo and he is not able to comment how such solution could benefit him in his daily tasks.

During the workshop it was discussed that how could this kind of observation application be split into smaller parts. Participants defined three functionality levels for the application:

- First level: the user can observe data.
- Second level: application can direct user and user attention to occurring problems.
- Third level: user can interact and fix occurring issues.

Updated requirement specification was based on this definition. As we had almost achieved a basic support for the first level, we also targeted the second level functionalities in the second iteration. The revisited requirements included:

- Add support for visualizing error situations.
- Add support for pointing the user camera / eyes to the error direction.
- Investigate a method to highlight the occurring error.

Development was started by adding simple exit door and textures for the scene (Figure 28). As the application was still using test data from test data API it was decided that we move the status data into a flat file which is stored within the device itself. Thereby support for API communication was partially revoked to focus more on the virtual reality side of the prototype.

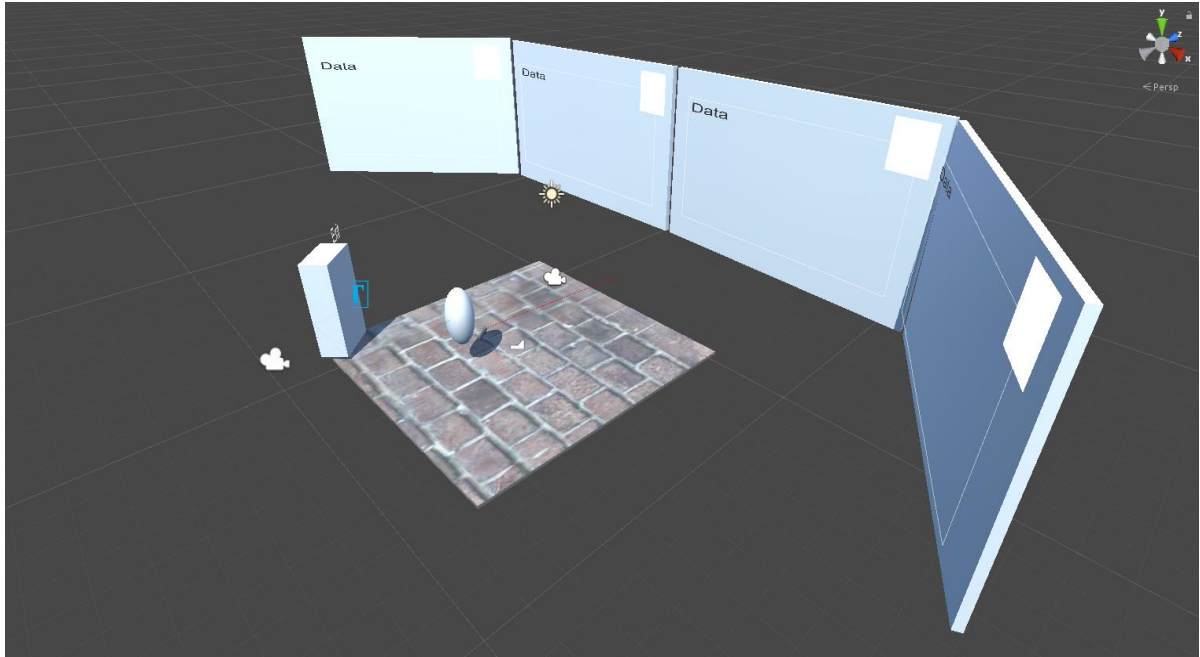


Figure 28. Observation room with textures.

After adding textures to the scene, the development was focused on enhancing the observation functionalities such as camera control and error highlighting (Figure 29). Status data was complemented with a representational icon, notification sound and user's direction of gaze was automatically pointed to the direction of the occurring error.

For demonstration purposes the scene was complemented with a script which randomly switched the error between the screens every 10 seconds. This mimicked a real-life scenario where problems would be fixed and occurring again.

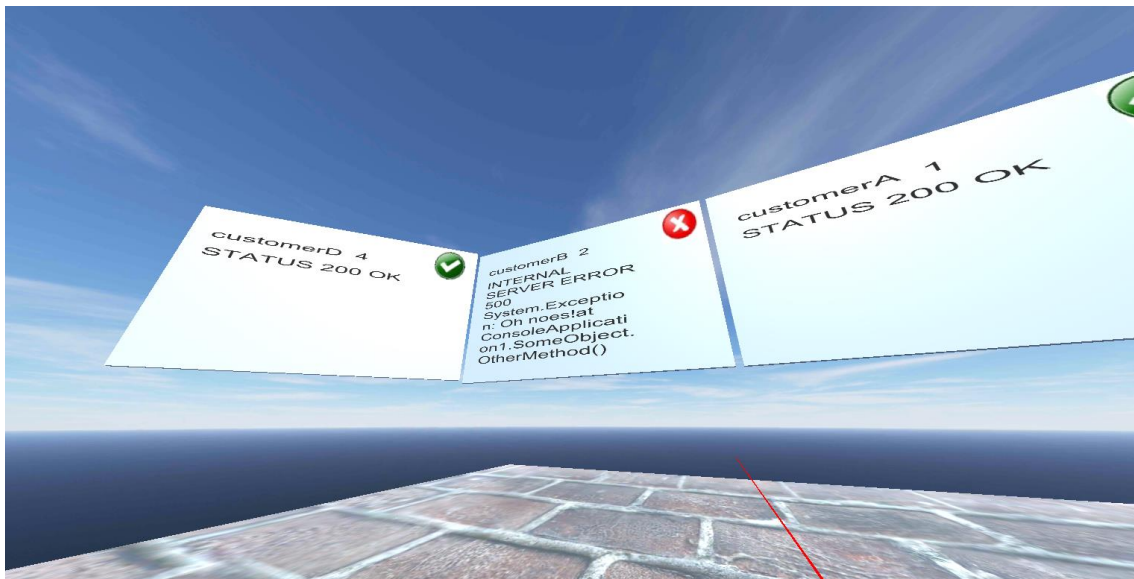


Figure 29. Information screens.

The development was halted after second sprint. Participants were asked to describe how they liked the development process and selected methods: co-design and prototyping. Participants told that they enjoyed co-design and it was a motivating way to participate

people in the development. Prototyping was more challenging: they felt that it was rewarding to see how their decisions helped to direct the development of the prototypes on different stages, but it also had a downside. The system specialist felt that he could not properly contribute on the development during very early stages of prototyping whereas the transition manager enjoyed the current process but said that he would not be too interested in the later stage of development where we would do practical testing with the system.

Compared to the transition manager the system specialists' job description is a lot more practical. System specialists' interests were also on more practical level compared to the transition managers. This may be interpreted as a need to utilize people with different perspectives and interests on different stages of prototyping: managers and other employees with wide understanding of the business on early level of design and practical workers during the later stages of the prototyping and testing.

Prototype development could be continued by investigating Bluetooth keyboard support for the virtual goggles, existing ticket system integration into the virtual world through e.g. webviews and by processing realistic mock data in the application. After these features the application usability could be tested in a role-playing session similar to French and Teal [2015].

## 6 Discussion

### 6.1 Research findings versus earlier scientific background

Our research question was how co-design fits virtual reality product development project and how does it perform while introducing a whole new industry for the employees. Answers were sought by an action design research where both co-design and prototyping were utilized in workshops. As a result, multiple IT artefacts were formed. Artefacts were shaped through multiple iterations and eventually presented for the rest of the local employees.

Based on the research results it is safe to assume that co-design fits virtual reality product development project well. Compared to earlier studies of Trischler et al. [2017] and Steen et al. [2011] we achieved same outcomes and positive traits of co-design. Participants especially described the co-design as an engaging and motivating development method. From the researcher point of view co-design was also an effective tool while discussing the domain specific details and specifics with the practitioners. Piloting with a new industry did not cause any unpredicted side effects: challenge of too optimistic scheduling and variable speed of application development can be described as a common malediction of software industry. Besides it our venture with virtual reality was rather smooth sailing.

Majority of the participants also felt that prototyping was a compelling development method which is in line with the studies of Trischler et al. [2017] and Yang [2005]. It also fit well with co-design. What we learned was that different kind of participants should be utilized during the different stages of prototyping: hands-on workers may feel less committed during the early stages prototyping whereas the management might prefer to operate and design on a higher abstraction level. Unity was also a powerful tool for prototyping. In addition to low-fidelity pen and paper prototypes we were able to sculpt the virtual environment live with the participants in workshops.

Due to the strict schedule of the research the actual application development was limited to two to three iterations per artefact. With some additional development the applications could be tested with role playing sessions like French and Teal [2015]. This would help to improve the usability of the applications and verify the results of co-design in practice.

### 6.2 Thesis process review

Virtual reality as a concept was interesting. We were glad to find out that the surrounding organisation from practitioners to the management was also keen to learn more of it. We believe that this was partially thanks to our research regarding the competitors and their service catalogue where virtual reality was represented. Very soon we had an agreement of a common goal and development target. Scientific background was also robust and co-design and prototyping fit the product development target well. We also found similarities between ADR and agile methodologies of software industry which helped the development process a lot.

The thesis work was started mid-December in 2018 and it was finished by the end of April 2019. During the circa four months of work we first defined the initial scope, studied scientific background, searched and invited the participants, concluded theme interviews, learned the related technologies, implemented multiple iterations of design and

development work and held an open form survey for local employees. We are satisfied with the results even though with longer schedule we could have been able to deliver more polished artefacts and more scientific contribution.

While observing the past months and concluded design and development work we have recommendations for similar future studies: select your hardware by the defined development target and do not try to do it the other way around as the limitations of wrong hardware may become very hard to bypass. By accepting the Oculus Go goggles as our target hardware before carrying out any interview or design work we ended up in a situation where hardware limitations steered our work.

Other recommendation is regarding the use of ADR in an organisational setting. The ADR is a powerful tool capable of delivering significant results, but the process needs boundaries and continuous steering. First, we had somewhat open schedule for the development and communication between the participants was very irregular. After setting fixed iteration lengths and agreeing on workshop dates weeks beforehand we started seeing tactful and concrete development and results.

### **6.3 Practical findings**

Right from the very first discussions regarding virtual reality development in Digia it was noted that employees think that they and their customers could benefit from virtual reality solutions. The message got stronger the further our development evolved and eventually we decided to hold an open form survey where interested Tampere area employees could visit and review our prototypes, prototyping process and answer if they would like to see Digia entering a new industry: virtual reality. Even though the invitations for the form survey were sent just couple hours prior to the event we got 23 unique visitors from 6 different business areas. Survey question and answers can be found in the attachment section (attachment 1.).

Significant survey findings were that every survey participant was interested in virtual reality on some level, clear majority reported that observing the prototypes and prototyping process gave them new ideas, everyone thought that Digias customers would benefit from virtual reality solutions and over half reported that they could name a possible sales lead regarding virtual reality.

Employees who closely worked with manufacturing industry stated that their clients might benefit a lot from augmented reality solutions (AR). AR is an interactive environment where a real-world is augmented by computer-generated information across multiple sensors such as visual, auditory and haptic [Huffington Post 2016]. We recommend investigating this topic as a separate study at Digia.

Technically Unity framework was a pleasure to work on and we can recommend further ventures with it. What should be considered is the hardware platform: Oculus. Oculus Go goggles were very painful to develop with as they did not support live debugging straight through Unity editor but required a compiling and deployment between every change. Debugging and tracing problems was also challenging as you had to either print error messages into the screen of the goggles or use ADB. Oculus offers improved functionalities with their more expensive model: Oculus Rift. Rift also offers improved controller

layout and better software libraries for Unity. Other hardware providers such as HTC and Samsung could also be considered.

All in all, we think that this research offered benefits to all its stakeholders. We are grateful for Digia for giving us the chance to study this topic. We sincerely believe that we have unveiled a new business opportunity for the company which is just awaiting a kick-off of a pilot project with a pioneer customer.

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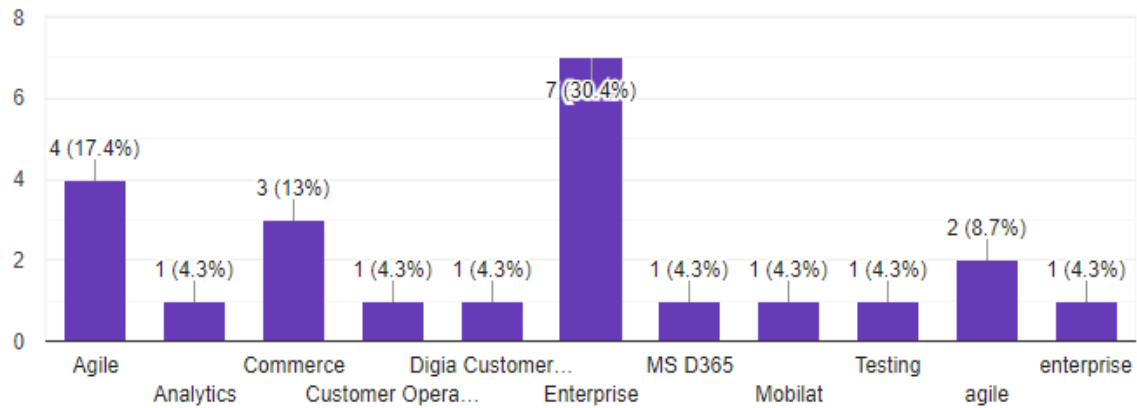
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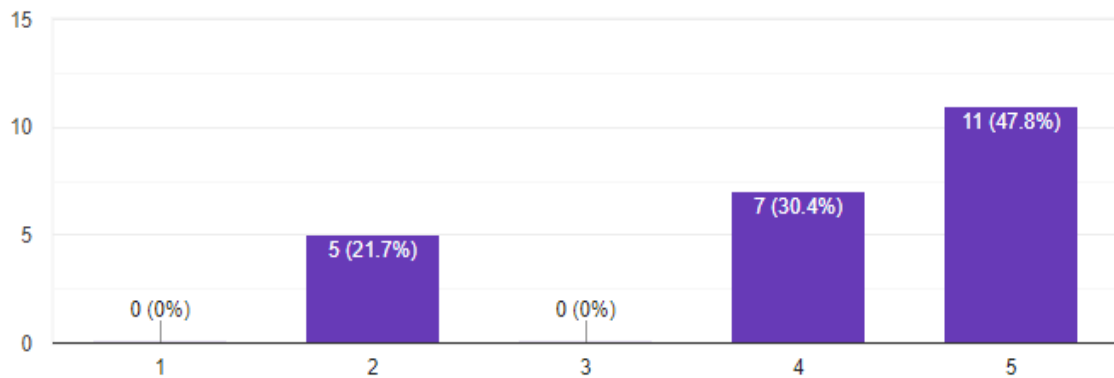
Attachment 1: Survey questions and answers.

Virtual reality form survey

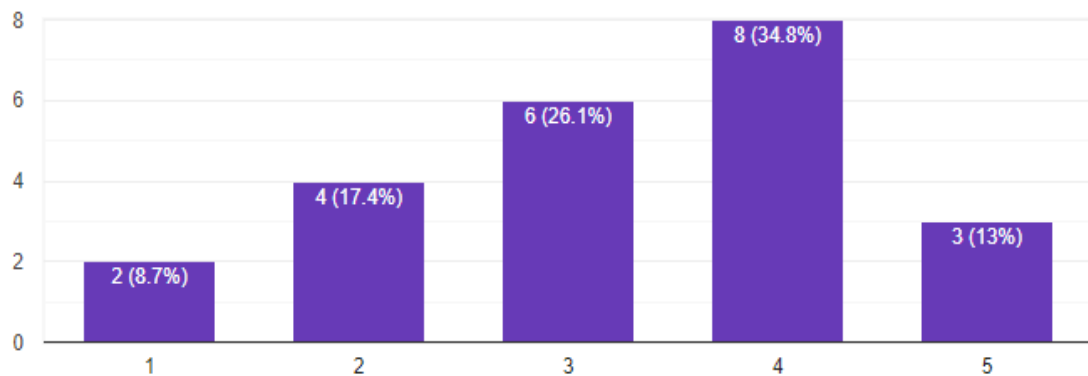
1. Organization (free form, results simplified in the research).



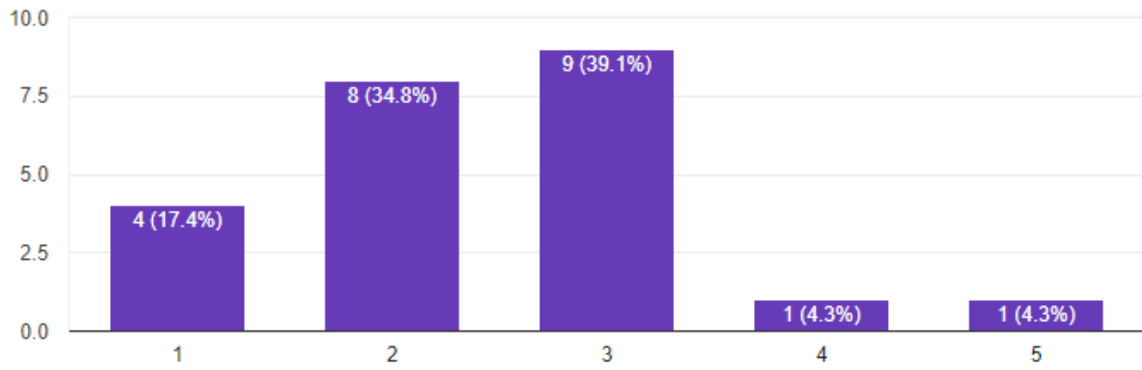
2. I am interested in virtual reality (low-high).



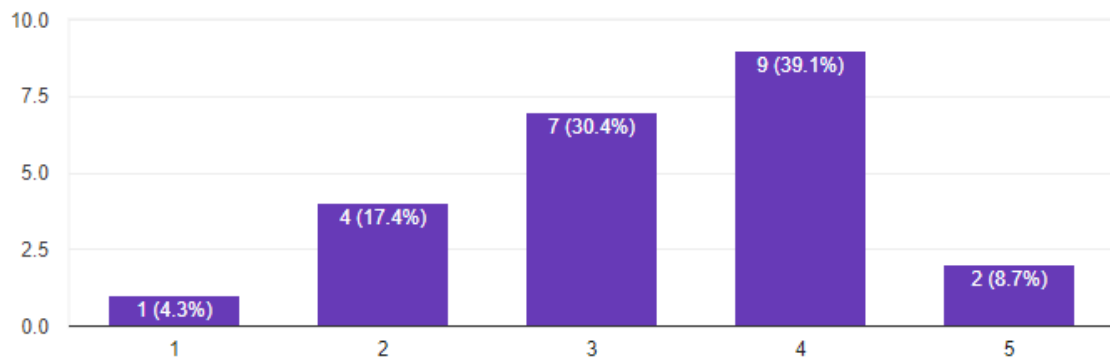
3. Observing the virtual prototypes and prototype process gave me new ideas (low-high).



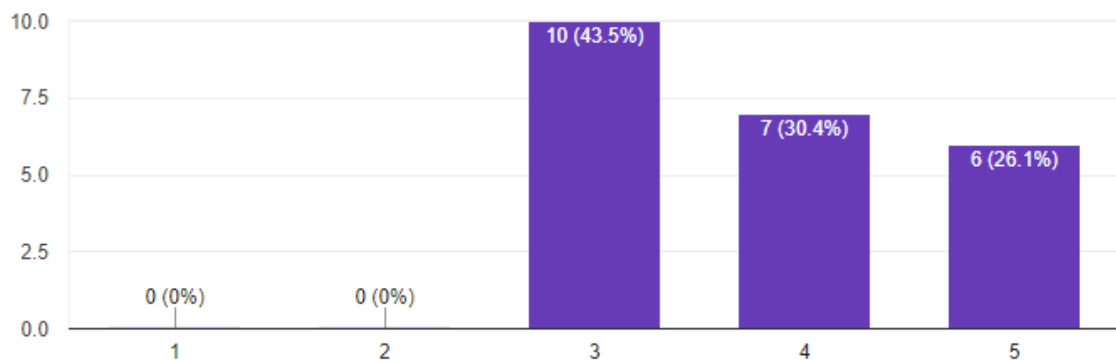
4. Virtual reality would benefit me in my daily tasks (low-high).



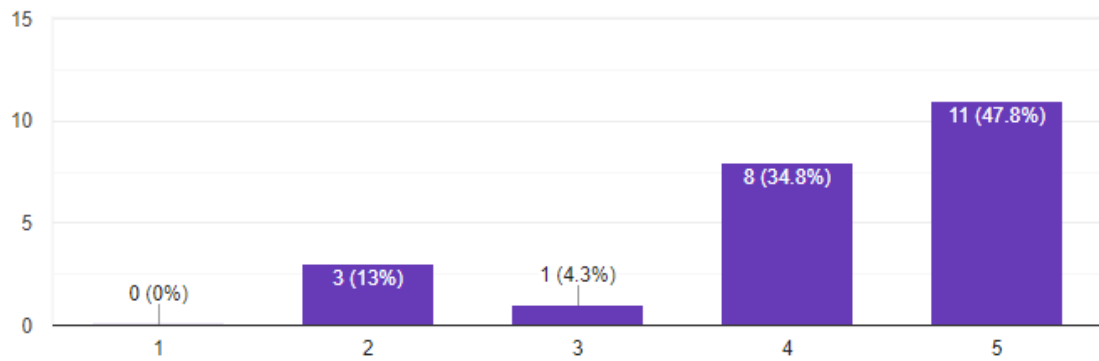
5. Virtual reality would benefit my customers (low-high).



6. Virtual reality would benefit other customers of Digia (low-high).



7. I would like to see Digia to invest in virtual reality in the future (low-high).



8. I can name N customers who could be interested in virtual reality if the idea is sold properly (0-10).

