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Multidisciplinary development of Smart Jacket for Elderly Care

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Abstract

The objective of this thesis was to seek solution for two challenges daily met in practical work with elderly: dressing upper body cloth might be a challenge and the nurse call -button is a challenging to press. These two challenges are bound in same region of the body and thesis writer was willing to attempt to seek solution for these practical issues. Another aim was to describe the best practices in product development process.

This thesis reports multidisciplinary product development process of an upper body cloth that has a nurse call – button attached. This thesis followed the Design Thinking process and included the four tangible prototypes, four different workshops and a laboratory study. The Smart Jacket is multidisciplinary creation by professionals of Satakunta University of Applied Sciences, Tampere University, and professionals in Senior Care.

Smart Jacket is the end result of this thesis. This upper body cloth can be dressed on without moving shoulder joints. Nurse call -button is attached on chest and it does not need any fine motoric skills to operate. Smart Jacket is a decent example of collaboration: all stakeholders contributed to development of Smart Jacket. The nurse call -button works with passive ultra-high-frequency (UHF) Radio Frequency IDentification technology. The laboratory study's results are promising: Smart Jacket's nurse call -button is operative and approve that it could be applied in practical use. The reading range on person is approximately 4,3 meters (in 867,6MHz) which might indicate reasonable potential to imbed this kind of alarm system in health care facilities in future. Further studies are needed how the described technology could be implemented indoor use. Further research is also needed to study the products suitability with other user groups.

Key words
Smart Wearable, Elderly, passive UHF RFID, Product development, Multidisciplinary development

CONTENTS

1 INTRODUCTION

Aging comes with various conditions lowering ability to move, reducing cognition and physical weakness (Pantelaki, Maggi & Krotti, 2020). In 2015 there were 46.8 million who suffered from dementia and rate is growing rapidly (Krysinska et al., 2019). Ministry of social affairs and health (2020, 22) claim that progressive memory conditions are remarkable financial challenge and risk for public health. There is a need for safety improving in care homes hence the customers expectedly have many impairments and adverse events like falls (Damery, Flanagan, Rai & Combes, 2017). Majority of care units already use monitoring systems or nurse call applications (Website of Vanhustyön keskusliitto, 2019). Technology that can be implemented into home environments are still needed (Ministry social affairs and health, 2020, 33). Wristbands, cords, sensor mats and buttons are used so elderly people can express the need of help. Wearable technology especially integrated within clothing is still rarely - if at all - used. Sometimes wearable technology can create stigma perception, and this should be taken under consideration in design process (Li, Lee & Xu, 2020). Farivar, Abouzahra and Ghasemaghaei (2020) did note that perceived complexity (reading the output and understanding it) of wearable device is barrier to usage. They found out that elderlies' perceived well-being influences the motivation to use wearable device: when elderlies' perceived well-being is reduced its effects positively on intentions to use wearable device.

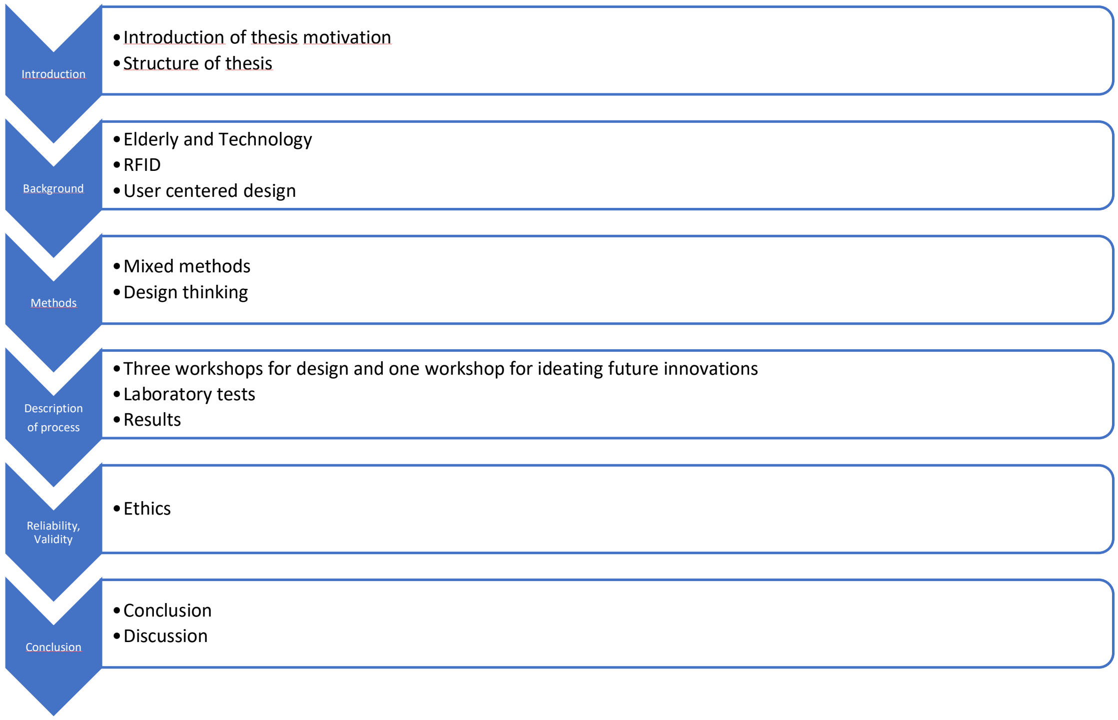
1.1 Aim of the thesis

The aim of this thesis is 1. To develop a prototype of user-centered smart jacket that has a nurse call -button. 2. To describe the best practice of multidisciplinary development process. These aims are referred in this thesis as goals or challenges.

This thesis process describes development process as iterative where prototype is improved continuously based on feedback. As information gathering workshops were arranged and the results are reported in this thesis. The prototype was validated in laboratory conditions. As end results smart jackets were created, ideas for further studies were made and the best practices for multidisciplinary development were described.

1.2 Structure of this thesis

This thesis consists of six chapters. The structure of this thesis is shown in Picture 1. Chapter 1 introduces the aims and motivation of this thesis. Thesis structure is found in chapter one. Chapter 2 enriches the background for this thesis. Chapter three introduces the methodology of this thesis. In chapter 4 are described the product development process and result from this research. Chapter 5 focuses on evaluating the ethical aspects and validity of this thesis. Finally in chapter 6 is conclusion and discussion.



Picture 1. Structure of this thesis

2 BACKGROUND

2.1 Elderly

World Health Organization (2018) defines aged being a person to be over 60 years. Statistics show that there are 874 00 over 70-years old in Finland, raising dependency ratio was highest ever being 61,4 (Website of Statistics Finland, 2019). Aging causes functional and physical losses. Diseases can affect perceived quality of life, independence, and mobility (Grimmer et al., 2019).

2.1.1 Changes among aging

Aging comes with different kinds of physical changes. It effects on posture, reduces muscle tissue and balance, and has effects on mobility. (Pantelaki, Maggi & Krotti, 2020.) Osteoarthritis and spasticity are common in elderly, and they make moving more complicated (Grimmer et al., 2019): Joint pain can be persistent, can lower physical activity and might reduce perceived quality of life (Bullbock et al., 2019). According to National Institute of Neurological Disorders and Stroke spasticity increases muscle tone or muscle stiffness in abnormal way. Spasticity might cause discomfort or pain. (Website of NINDS, 2019.)

Pantelaki, Maggi & Crotti (2020) did note that motoric skills are weakened in elderly, and it showed in movement duration, deceleration phased and increased sub movements. Shimoda et al. (2017) did study age-related decline in control of preprogramed movement and results indicated that younger (people under 59 years) have better control of preprogramed movement than older.

Cognition has remarkable meaning when it comes to elderly functional independence. Dementia causes challenges in health and social life and disables elderly. It is estimated that in 2050 there are 115 million people suffering dementia, now the rate is 40 million. Reduction on cognition effects on problem-solving, memory, attention, and verbal expression. (Bahar-Fuchs et al., 2019.) Although cognition is known reduced when aging there are several ways to enhance cognitive skills: Living intellectually stimulative and physically active life are factors that promote cognition (Livingston et al., 2020).

2.1.2 Elderly and technology assisted living

Finnish institute for health and welfare align, it is a national goal to enable elderly to live at home if possible and technology can be used as increasing safety at homes of elderly (website of THL, 2020). In Finland care services can be offered directly to homes. When domestic care is not enough residential care and sheltered housing is offered. (Website of Ministry of social affairs and health n.d.)

Whether the elder is at home or in a care home, most safety companies offer wristband as solution to keep “Nurse call button” or “emergency button” nearby. Wrist bracelet is usually connected to mobile device that Care giver is using. Bracelet can be linked in a hub that is used to share information to different devices. (Website of Vivago n.d.;

Website of Tunstall 2021; Website of 9solutions n.d.; Website of Everon n.d. & Website of Ascom n.d.) New innovative ways to delay hospitalization is already implemented: videocalls from care professionals to check up elderly, monitoring and surveillance solutions and medical robots are already in use. (Ministry of social affairs and health, 2020, 33-35). Nauha et al. (2018) concludes that assistive technology can support the care of person with memory reduction.

2.1.3 Smart clothing

Wearable Technology is technology that can be worn or kept close to person. Wearable Technology can be subcategorized in two different concepts: Primary and secondary wearable devices. Independently working devices like wrist worn tracker is primary and sensor attached nearby heart are secondary as it only follows the rate and sends data to primary devices. (Godfrey et al., 2018.) Wearable Technology has different kinds of outcomes: Smart glasses to key trackers and smart rings (Picture 2). Often, they collect data from customers bodily functions as heart rate and blood pressure. Commonly these wearable technological applications are used to monitor physical activity. In example rest homes use wearable technology to monitor vitals of elderly people. (Rodrigues et al., 2018.)

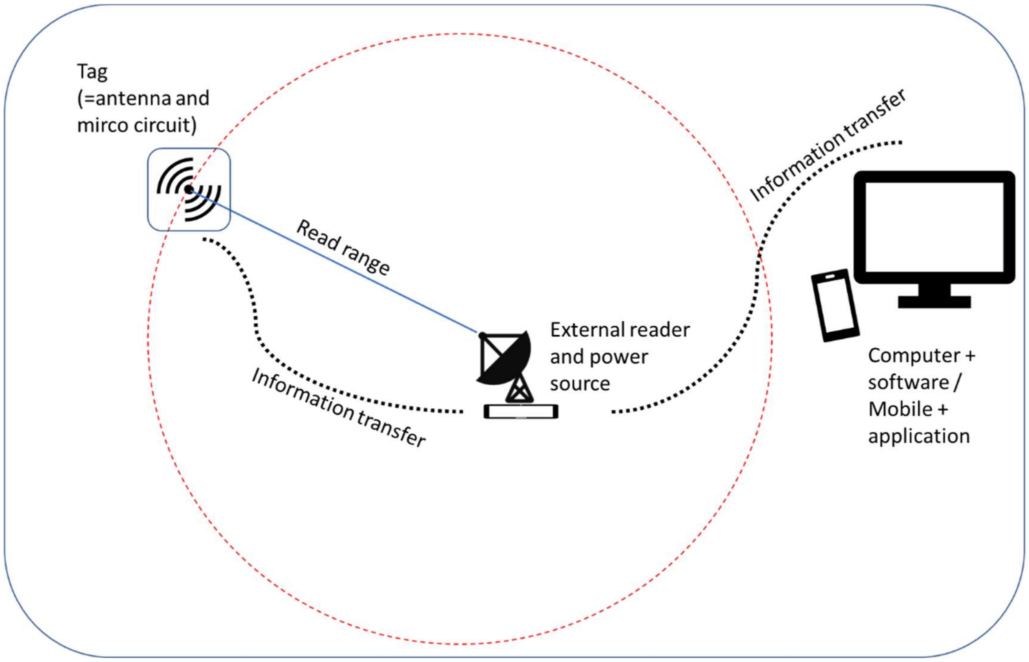
Picture 2. Wearable Technology (Rodrigues et.al., 2018)

In 2018 Lin et.al. did propose intelligent health monitor system. They created smart clothing that was connected to care institution control platform. The sensors did follow i.e. heart rate and had fall detection. Radio frequency identification has shown its potential when embedding technology into clothing (Mehmood et. al 2020).

2.2 RFID

Radio Frequency identification (RFID) is technology that uses radio waves as communication trait. The information needed is received utilizing backscatter from radio waves (Picture 2). The nature of RFID is that it is automatic and does not need direct contact to work. RFID technology is mainly used to identification purposes and tracking but depending on tag type RFID can also be used as sensor for i.e., humidity, sound, pressure, temperature, air of water quality, position and weight (Bensky, 2019,1-3, 393). Hasani (2018, 42) declared that advantages of RFID tag are easily implemented, cost-effective, durable in harsh conditions and it can be installed different purposes.

RFID works in wireless sensor networks (WSN) that makes internet of Things (IoT) possible. The RFID gather the information of subjects (such as tracking them) and WSN collects the information and shares the information with devices attached. With WSN the RFID can be connected I.e. mobile applications and its used broadly in security and medical application. (Landaluce et al., 2020.)



Picture 3. RFID technology basis. Tag consists of antenna and micro circuit. External reader has also a power source, information is changed via this wireless connection. External reader and power source is connected wireless to computer, information from tag is turned readable with software. The distance between power source and tag is called read range. Tag, external power source and device where output can be red works in wireless sensor networks.

2.2.1 Components of RFID

RFID technology consists of tag antenna(s) commonly called as transponders, reader antenna, reader, and background system (Picture 3). The transponder or tag has usually no own energy source and it can be attached to object. Transponder includes antenna with circuits. Circuits hold in a serial number that is used to identify specific tag. The reader-is used for information gathering: It has energy source, and it receives information from tag first identifying the chip. RFID reader communicates with the background system which utilizes the tag ID data further. (Bensky, 2019, 5-7.)

RFID tags are divided in three different groups based on operating principles. There can be passive antennas, semi-passive and active. Passive tags utilize the backscatter waves, semi-passive tag consist own power source but also rely on backscatter and active tag has power source and transmitter. Passive RFID tag working area is electromagnetic field that is created by the reader. Passive RFID tag can be coupled in two ways called near field and far field coupling. Near field tags engages magnetic fields whereas the far field tag uses electromagnetic waves. Far field antennas read range is long (5-20m) and near field (<0,5m) tag has short transmission ranges. (Chen, 2018; Pahlavan, 2019; website of RFIDjournal, 2020.)

RFID tags parts are electronic circuit, antenna, and substrate material. The electronic circuit is a small microprocessor that needs power to work. In passive tag, power comes from the reader. The largest component of the tag is antenna, and it is connected to microchip. In passive RFID tags antenna reflects the signals. The electronic circuit get power from radio wave via antenna. Aluminum, copper, and silver are commonly used as material of antenna. The shape of antenna varies due used frequencies and application requirements. (Hasani, 2018.) Tag can be attached to adaptable surface, such as fabric that puts the tag in demanding conditions when the aim is to obtain the performance of RFID solution (Khan et al., 2019). Xiaochen (2019,17,53) wrote that those antennas in RFID tags in clothing should be stretchable, flexible, and durable to get comfortable wearable solutions.

Frequency ranges that RFID systems commonly use are low frequency, LF (approximately 125kHz) high frequency, HF (approximately 13.56MHz), ultra-high frequency, UHF (approximately 868 and 928MHz) and microwave (2.45 and 5.8GHz). (Aragón-Zavala, 2017, 3.) As countries have decided their own operative regulatory i.e., UHF band allocation is in Finland 865.5-867.6 and Russia 866-867 MHz; in United States and Canada 902-928 MHz; and in Australia 918-926 MHz (GS1, 2021).

2.2.2 Rules and regulations for Radio Frequency allocation

Finnish Transport and Communication agency, Traficom, sets regulations concerning radio frequency. The aim of regulation is to “*guarantee a fair availability of radio frequencies and efficient, appropriate and sufficiently interference-free use of frequencies*”. The rules also apply the ISM-equipment that are used to generate radio frequency. ISM-equipment are electronical devices that industrial, scientific, or medical purposes. Rules and regulations reclined by International telecommunications Union (ITU) and European commission are accommodated within Traficom’s Radio Frequency regulation 4. (Website of Traficom, 2021.)

2.2.3 RFID challenges

As the architecture of RFID communication is open, the security questions are a challenge. The most common attacks toward RFID system are Tag isolation or tag cloning or destroying tag remotely, Denial of service, command injection, signal replaying and signal intercept with active device. The attacks are done mostly to access to personal data and to personal tracking. (Fernández-Caramés et al., 2017.)

Mansoor et al. (2019) wrote an article about Securing IoT-Based RFID Systems: A Robust Authentication Protocol Using Symmetric Cryptography. In the article the researchers did note that many protocols are developed securing RFID systems from external attacks and most of them still has their weaknesses in coding.

The read range of radio wave correlate to challenges dealt interference and noise: the longer distance between antenna and reader the more challenges occur what comes to noise and interference. Noise influencing communication quality (reader's ability to identicate signal) can be reduced with antenna adjusting or grounding the components. Sometimes shielding can fade unneeded noise. Beneficial would be to alter the noise source. (Lehpamer, 2012, 198, 200). RFID solution made for human tracking will note that the noise is from body tissues, and it has impact on i.e., reflection, attenuation, and propagation (Bouhassoune et al., 2020).

While RFID industry on health care is growing, the risks of the technology are also evaluated. Over a decade ago Van der Togt et al. (2008) did assess two RFID systems causes to 41 medical devices. They classified impacts in three categories: hazardous, significant, or light. Researchers did 123 tests (three tests per device) and 22 of them were categorized as hazardous.

Seideman et al. (2009) did conduct an in vitro research RFID technology interfering implantable pacemaker and implantable cardioverter-defibrillators. They found out that RFID readers did cause EMI (Electro Magnetic Interference) with medical devices. Study results indicate that more EMI were found to be LF readers and HF readers. UHF readers did not cause any EMI in the study tests. It seems that proximity causes EMI more than distant location. The researchers write that FDA has not gotten any incidents reports concerning pacemakers and EMI from RFID devices. The researchers deliberate that it could be reflecting "*low clinical risk*". They concluded that risks with medical devices should be taken account in medical device manufacturing and RFID industry.

2.3 RFID in health care

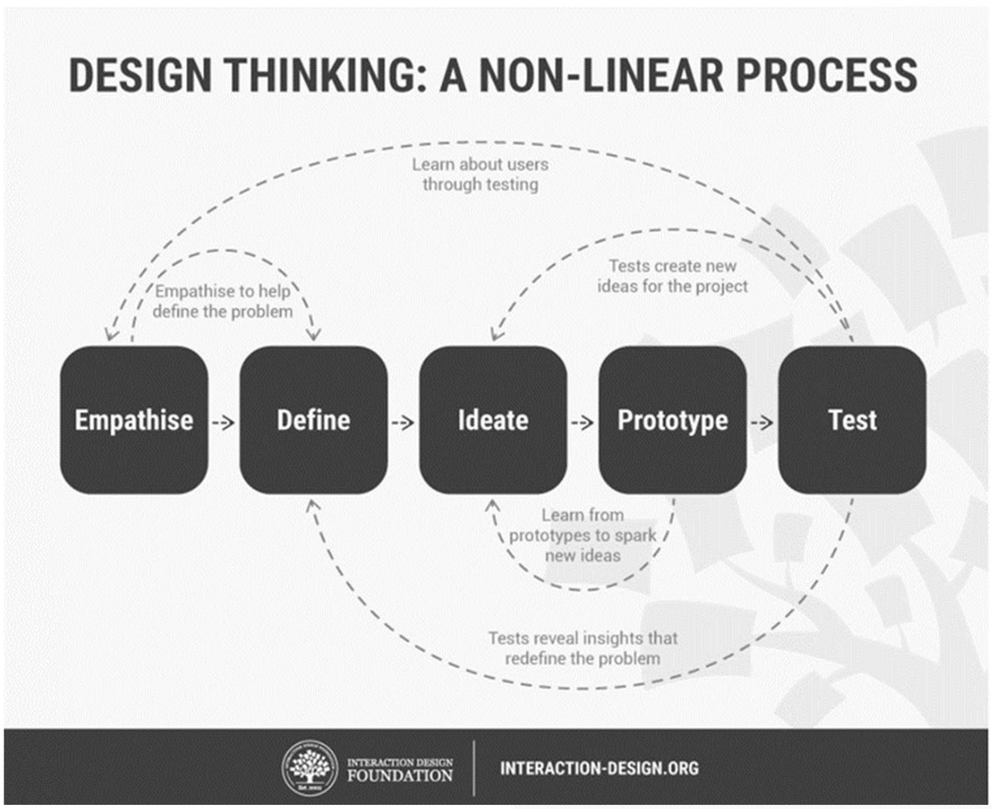
RFID can be found beneficial multiple ways in health care: tracking, ID and security control are already employed in variable manners in structures of health care. Promising RFID ecosystems are about to achieve practical use to mention few: patient monitoring, patient tracking, medical surveillance, blood bag verification and diet controlling (Rahman, Bhuivan & Ahamed, 2017, 4.) In 2018 Haddara and Staaby researched RFID applications in health care through literature review and suggested that main barriers RFID adoption in health care are expenditures, security and privacy challenges and patient safety concerns.

Yang et al. (2019) did create settings were passive RFID-based recognition system that detected activity. The research was experimental, and they conducted the study in elderly care unit's living room. They installed 6 antennas around living room, there was one reader in the room. 29 tags were attached to things like spoon, towel and trousers. Read range of used tags and antennas were 3-4 meters. They did create a model for activity tracking and found that recognition accuracy was 82,78%, according to them it is proof of effectiveness of used method. Zhu et al. (2017) did use RFID to detect falls by movement detection.

2.4 User centered product development

Ulrich and Eppinger writes that product development is a set of activities. Product development starts with understanding of market opportunity and ends when product is in sale. In product development, crucial is to identify customer needs. They did describe a concept of development process that contains journey of processes: firstly, clarifying the mission, identifying the customer needs, and making a prototype (tangible or blueprint) ant testing them. The end product is the result of development process. (Ulrich & Eppinger, 2020.)

Design thinking (Picture 4) is process that seeks understanding the user and tries to create solutions based in user understanding. Design thinking process is iterative and unpredictable (Dam & Siang, 2020; Tomitsch, et al., 2018, 13). The aim of user centered design is to include customer's participation as much as possible (Deuff & Cosquer, 2013).



Picture 4. Design thinking: A non-linear process (Teo Yu Siang and Interaction Design Foundation. Copyright terms and licence: CC BY-NC-SA 3.0)

The Design Thinking process starts from empathizing. This phase is to get deep understanding of customer needs. In defining phase designer defines the goals and clarifies the boundary conditions, in a way finds a way to make sense to upcoming process. Ideation phase is to find executable design solutions. The prototypes (tangible or blueprint) are created in prototype phase. In test phase the goal is to get feedback from users and other stakeholders involved. (Curedale, 2016, 122-125.)

2.4.1 Inclusive design

Concepts of “design for disability”, “barrier free design”, “design for all”, “universal design”, “transgenerational design” and “inclusive design” are driving for the equal rights for all in society and marketplace. While the first two terms incline the rights of those with disabilities, the two latter terms (transgenerational design and inclusive design) cause a slight pressure to reassess the designing goals. Expression “inclusive design” request designers in education, management, and research to quest new ways of thinking. (Coleman et al., 2007, 12,13.)

The National Disability Authority (NDA) have published 7 principles of universal design:

1. Equitable use
2. Flexibility in use
3. Simple and intuitive to use
4. Perceptible information
5. Tolerance for error
6. Low physical effort
7. Size and space for approach and use

With these seven rules the product or service can be evaluated from different standpoints. The first rule is that product should be equitable to use. This means that the product is usable and marketable for people with different abilities. The goal is to avoid stigmatizing, product should be aesthetic, and privacy, security and safety matters should be equally available. Principle two, flexibility, means that design should accommodate the user’s abilities and preferences. Third principle tries to make sure that product is easy to use regardless the user’s abilities. The fourth principle is that product present effectively to user the needed information regardless the user’s abilities. This could i.e., mean different ways of communication (verbal, with picture etc.). Fifth principal is to minimize harms and unintended actions. This could mean product is warning errors of its actions. The sixth principle is: Low physical effort. That means the product should be used efficiently with low physical effort. The last principle tries to secure that the product can be used regardless customers physical features. (Coleman et al., 2007, 24; website of NDA, 2020.)

2.4.2 Creativity

According to Lei et.al (2020) creativity can appear in individual, when individuals interact, it can be produced in group work and in multilevel systems. Creativity can be generated, influenced, or constructed depending on surrounding circumstances. Creative Education Foundation shares understanding of creativeness and its common traits. According CEF creativity is imaginative, process centered and original and might be intentional. Every individual has a potential to be creative. Free creative process might have some barriers bound to resources, time, culture, judgement (internal or external) and perceptions towards talent or skills. Identifying the barriers is crucial when thinking creative. CEF also shares bridges that support creativity: open mindedness, appreciation to change and creating a climate that encourages to creativeness (mental or physical). (Franko et al., 2017.)

3 METHODOLOGY

In this chapter is described the methodology of this thesis. This thesis is product development project and is conducted by design thinking process. Design thinking could be applied to health care innovation processes (Altman 2018). This thesis's outcomes require the participation of different stakeholders. The information is gathered using mixed methods depending what kind of information is needed.

3.1 Mixed methods approach

Mixed method research combines two research methods: qualitative and quantitative. The aim of this kind of approach is to deepen the quality of results. Phenomena searched with different approaches allows more extensive understanding and have effects on research credibility. To collect the data in a study, researcher can use methodologically qualitative approach. Data can be collected by observation, theme interview, literature resources, reports, and memos. The aim is to find deep and rich material. Quantitative research goal is to generalize and can be measured on statistic scale. Quantitative data collection might include measurements and tests. (Kananen, 2015; website of University of Jyväskylä 2010.) National Science Foundation defines proof-of-concept and prototype as following: "A proof-of-concept is the realization of a certain method or idea to ascertain its scientific or technological parameters." Fully understood proof-of-concept allows application areas recognized. (National Science Foundation, 2014.)

3.1.1 Workshop

Oxford's dictionary defines "workshop" as following: "A meeting at which a group of people engage in intensive discussion and activity on a particular subject or project" (Website of Oxford Lexico, 2021). The goal of a workshop is to gain information, participate people in dialog and innovate. A workshop time can often vary one hour to one weekend. When holding a workshop, one should note several challenges that may take place: participants knowledge may vary, and topic might be irrelevant to them; scheduling issues; resentment towards workshop leader; some participants may remain passive and some dominant and/or pre-work was not done well. When it comes to workshops advantages it is cost-effective and when succeed it might have positive impacts in group synergia and learning. Also new ideas are met when workshop is well made. With planning the mentioned challenges can be reduced and one factor to succeed is to frame the purpose of workshop. (Website of British Council, 2020.)

The workshop can be seen as a process that includes three different phases. At first there is a preparing phase where the facilitator is defining the subject, finds appropriate tool to use, identifies and selects potential participants and invites them to workshop. Creating a timetable to workshop and clearly ensuring the ownership of the new innovations. The second phase is conducting the workshop: Introduction is for practical reasons. Facilitator should make sure the goal is out said point legal issues of the ownership of the innovations. At the second phase the facilitator creates frame to ideation and generates new ideas with chosen tool. The facilitator words out the ideas, presents them and helps to evaluate them. The third phase is at the end of the workshop. The third phase is for protection of the workshop. The facilitator will conclude the new ideas and makes preliminary plan what will happen to idea and how it will remain protected before implementation. (Website of University of Vaasa 2019a.)

3.1.2 Facilitator

Facilitator is someone who eases group processes. The facilitators aim is to help group to act in constructive way. Facilitator is neutral persona and does not give any solutions, thus, the answer is to group to find. Facilitator's role is to select the appropriate method for workshop and keep structure in it. At the beginning of the workshop, facilitator introduces participants, sets the tune, and helps participants to focus. Facilitator tells the workshop rules for participants. At the end of the event facilitator is the one who makes summary of the event. (Kantojärvi, 2017, 11.)

3.1.3 Brainstorming

Alex Osborn did define Brainstorming as "group's attempt to find a solution for a specific problem by amassing ideas all the ideas spontaneously by its members" (website of American Association of Advertising Agency, 2021). University of Vaasa offer brainstorming as a tool for ideation process. According to Vaasa University brainstorming fits when services are developed and when ideation is organized in groups. It can be used independently, and it does not need any other tools to complete it. Brainstorming's aim is to produce large number of new ideas in short period of time. Starting point is to have a challenge and via brainstorming participants try to find solutions for it. With brainstorming participants can be free from their typical mindset. (Website of University of Vaasa, 2018a.)

Various researchers' guidebook commonly present seven basic rules that set the frame to brainstorming. The rules vary slightly depending of the author but are often described as follows: Do not judge; Prefer ideas more imaginative; Continue developing other's ideas; Focus on new ideas; Use visualization; Listen all the ideas to be heard and highlight the quantity not quality. (Isaksen, 1998; Liu & Schönwetter, 2004; Website of University of Vaasa, 2018b.)

3.2 Research challenges

This thesis research challenges are 1. To develop a prototype of user-centered smart jacket that has a nurse call -button. 2. To describe the best practice of multidisciplinary development process. These aims are referred in this thesis as goals or challenges.

To support thesis' empirical outcomes and create more credibility, also laboratory tests were needed. The aim for laboratory part was to find answers to: does RFID technology work on Smart Jacket? Does the blockage of radio frequency signal work? What is the read range for this jacket?

3.3 Conducting this thesis

This development project is experimental and unpredictable. Project follows to be iterative and end solution cannot be defined strictly. The goal is to act fast and with small resources. Succeed in project can be measured how efficiently is learned in process and how well the learning is implemented. The process proceeds step by step and continuance is evaluated by the result of actions before. (Hassi, Paju & Maila, 2015.)

Thesis writer did choose design thinking process as methodological guide. The steps in development process were made using simplified journey map of design thinking, Picture 5. In Picture 5 are categorized five different development phases: empathize, define, ideate, prototype and test. In picture is also seen the used tools in particular phases.

Picture 5. Development process steps in this project

In empathizing phase there were work life observations made of the factor that could impact in dressing up. The original designs were compared, and user needs were indicated. Information was gathered into mind map as it is a tool for sense making. Mind maps visualize the concept. In this thesis mind map was used to visualize the challenges that might occur when elderly is clothing upper body or pushing a nurse call -button. Define phase is based in empathizing. For defining thesis challenges writer did Needs assessment.

For ideation phase, workshops were used for information gathering and tool used was brainstorming. In this thesis product development process, three different workshops were held to gather ideas to improve the prototypes. Thesis writer did facilitate all these three workshops. To clarifications the names of workshops are the following:

1. Workshop – Functional Design
2. Workshop – Adjusting Functionalities
3. Workshop - Ideas in practical use

Prototypes were sewn to get tangible item that concretes the innovation. Thesis writer did sew and made pattern pictures of all created prototypes. Four different kinds of proto cloth were made and onto one were the nurse call- button attached.

Testing phase were arranged with workshops and tool used were brainstorming. Laboratory testing were used for proof of concept. In product development idea gathering and testing jacket design for feedback three workshops were held. In testing phase there were also laboratory measurements on human and anechoic chamber to validate the performance of tag Human body causes loss in read range (Lehpamer, 2012, 198, 200; Bouhassoune et al. 2020). The measurements were taken with Voyantic Tagperformance.

3.4 Thesis schedule and settings

The thesis process did start in fall of 2019. Thesis writer did start to form framework concerning thesis in October 2019 and the first workshop was held November 2019. The product development process in this thesis included six organized meetings. The actualized dates, agendas and participants for meetings are presented in the following table 1.

Table 1 Product development process and actualized meetings

Action	Date	Agenda	Participants
The first workshop -Functional Design	Mon 4th Nov 2019	Present Prototype1 improvements	2 practical nurses 1 physiotherapist 1registered nurse 1 assistive worker
The second workshop -Adjusting functionalities	Mon 18th Nov 2019	Present Prototype2 improvements	2 assistive workers (other did participate last time) 1 practical nurse (did also participate first time) 1 registered nurse
Meeting at Tampere University	Wed 17th Feb 2020	Planning how to attach RFID tech to Smart jacket	Thesis writer and Johanna Virkki
Meeting at Tampere University	Tue 22nd of Sept 2020	Make Prototype 3 Attaching RFID onto jacket, Laboratory Study	Thesis writer Sari Merilampi Johanna Virkki and Adan Mehmood
The third workshop -ideas in practical use	Thu 24th Sept 2020	Present Prototype3 Improvements	2practical nurses (other did participate last time) 1physiotherapist 1registered nurse (did participate first time)
The fourth workshop -Smart Clothing workshop	9th Nov 2020	Prototype 4 Improvements, Future research	Thesis writer Sari Merilampi Selected professionals around world

As seen in table there were three workshops with jacket design as agenda. Then two meets at the Tampere University, first meet was to plan how attach antenna to fabric:

then to procedure the plan. The fourth workshop was thesis writer's opportunity to present the concept and gain more ideas to further development.

To get quality information and data thesis writer did choose participants to workshop from health care. It was important to get information from people that cope with phenomena daily and people that can express themselves adequately. Thesis writer did intake to arranged workshop practical nurses, physiotherapists assistive workers and registered nurses that work in care units for elderlies. They all had at least two years working experience from geriatric field, and they have knowhow about practical challenges when dressing up i.e., spastic person. Commonly the expert evaluation is used to gather information if actual target group is too challenging to include in research (Marinchenko 2019)

Thesis writer facilitated the workshops. Workshops were kept short because they were arranged between work shifts. The structure of all three workshops were align and started by opening the workshop, setting workshop rules and followed by the ideation and finally concluding the findings. Brainstorming was selected as a tool to ideate the smart jacket at the workshops. The goal for all three workshops were to answer question "how should we make it better?". All workshops were in Finnish to get more detailed and comprehensive dialog.

The ethical review statement was not essential since the study did not involve those who are vulnerable, (i.e. elderly or children), in thesis research was not included tests that could cause harm to participants. Also, participants were informed well, and they were voluntarily involved. (Tutkimuseettinen neuvottelukunta 2019). To note that any research permits were not applied, because the participants were representing themselves – not any organization. The organization did permit to conduct the workshops in care unit.

The COVID19 did set a challenge to conducting the workshops: The care facilities were closed from all third party presentative. Even within the facilities the transmissions were heavily restricted. This caused unexpected challenges and limitations arranging the workshops. This affected particularly to third workshop. The description of third workshop is presented in results.

4 RESULTS

This chapter consist of result gotten from research. Firstly, the main results are gathered. After the results for transparency and credibility, also the detailed description of product development process is described.

The Smart Jacket: The tangible results of this product development process were prototype 1, prototype 2, prototype 3 and prototype 4 (Picture 6). The assistive zipper were adjusted at first (prototype 1) to side and sleeve seam, but during development they were lifted on top of both sleeves. The prototype 4 has RFID tag attached to chest. Laboratory study demonstrated that tag is operative and can be merged with mobile application. The actual application is not part of this thesis. The aim of this laboratory part was to proof the RFID blockage can be used as nurse call -button.

The prototype 4 is dressable without moving users' limbs. The laboratory measurements resulted that the Smart Jacket was tested undistracted conditions, in unechoing chamber and on human. The measures did prove to be sufficient for operative actions. In this concept the operative nurse call -button. Tested ranges were achieved in legal band allocation in Finland. That being within 865-868MHz (Website of Traficom, 2021).

The aim was also to describe the best practices of product development process. With multidisciplinary collaboration Smart Jacket was created, without any of the included stakeholder, the outcome would have been different. If the product is developed quickly and with low costs, in limited schedule multiple cycles of ideate-prototype-test are possible. The detailed description should be written during the process. Design Thinking has been adapted also in health care and this thesis' findings are like earlier findings: customer friendly and profitable products and services are produced with design thinking.

Picture6: Prototype1 left up, Prototype2 right up, Prototype3 left down, Prototype4 left right

4.1 Detailed description of development process

This process is guided by the process of design thinking. Information gathering was made in workshops and brainstorming as tool. All the workshops were conducted in same pattern and basing the actions knowledge from theory part of this thesis. (Coleman et al., 2007; Deuff & Cosquer, 2013; Curedale, 2016; Franko et al., 2017; Tomitsch, et al., 2018; Dam & Siang, 2020; Lei et.al 2020; Ulrich & Eppinger, 2020; website of NDA, 2020.)

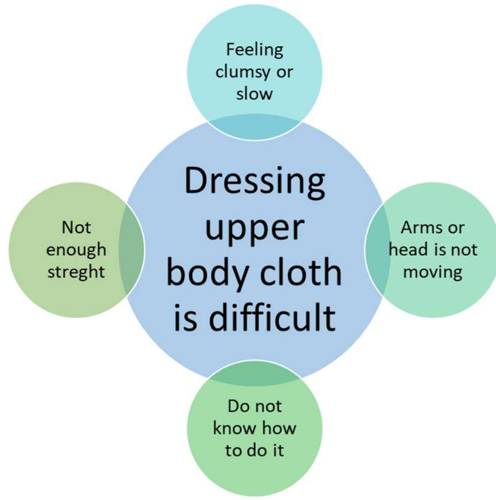
The following describes the product development process of Smart Jacket for elderly. The process is visualized in Picture 7 highlighting the phases analyzed. The first step is to Empathize.

Picture 7. Product development steps: Empathizing

4.1.1 Empathize

The need for different kind if upper body cloth is based in work life need. Often elderly suffer conditions effecting mobility (Grimmer et al., 2019 ; Pantelaki, Maggi & Krotti, 2020). Multiple conditions might affect the ability to dress up and complicate I.e., the use of assistive devices such as safety bracelets that require fine motoric skills. The goal of this phase is to empathize the reasons why dressing up might be challenging for elderly and why pushing the nurse call button might be challenging for elderly.

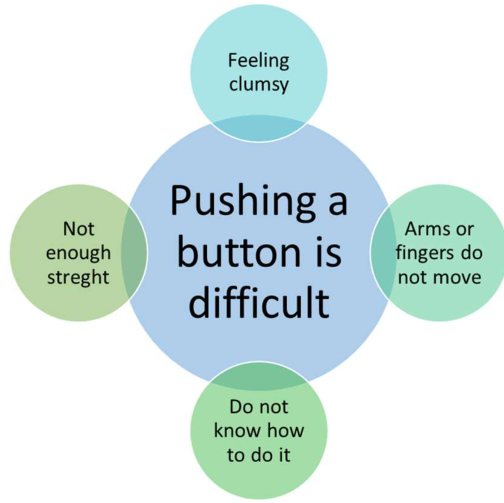
The upper body is more challenging to dress up than lower body. In Picture 8 is categorized why dressing up can be difficult. These factors are based in general knowledge from work life in elderly care units. These finding are results from observation and “in action” situations. However, they are also aligned with the extant literature concerning the challenges aging causes to elderly, information provided in chapter 2.



Picture 8 Challenges that might complicate elderly dressing upper body cloth

Common symptoms in joints and muscles are pain and stiffness (Website of NIND, 2019). Dressing upper body can be challenging for elder because arms or head does not move, or they have movement reduction. Often faced challenge is that shirts lack space underneath of armpits and if this space is added clothing start to get too big and loose, and they might appear clothing that perceive as “hospital clothing”. Sometimes elder can feel clumsy or dressing up can take more time than usual. Changes in motoric skills appear also in duration movement and inaccurate motoric maneuver (Pantelaki, Maggi & Crotti, 2020; Shimoda et al., 2017). Sometimes there is not enough strength to dress up (Bullbock et al., 2019). Often elder does not know how to do it i.e., elder suffering memory loss or is in such severe pain, that elder can perceive clothing up impossible.

Thesis writer observed other challenge raised from work life. Most of the care units for elderly already have patient safe controlling system including wearable device that can put on wrist or use as a necklace (Lin et al. 2018; Ministry of social affairs and health, 2020; website of Ascom n.d.; website of Everon n.d.; website of Tunstall 2021; Website of Vanhustyön keskusliitto, 2019; website of Vivago n.d. & website of 9solutions n.d.). In picture 8 is categorized the reasons why pushing a button can be challenging for elder.



Picture 8 Challenges met pushing a nurse call button in work life.

Pushing a nurse call -button can be difficult for elderly because arms or fingers do not move enough to meet the button: the wristband can be slid to wrong position and lack of movement in arm might make the push impossible. As Grimmer et al. (2019) established different physical conditions, such as spasticity might affect the ability to move. Elder might not know how to do it; this could be due cognitive abilities. Sometimes elder does not even remember it is a nurse call -button. In some cases, user does not have strength enough to make the push. Bahar-Fuchs et al. (2019) write that weakened cognition reduces problem-solving skills and disables elder. In other hand assistive technology is also seen as support to elderly if fitted to elderly's needs (Nauha et al. 2018). Ministry of social affairs and health (2020, 33) does state that new assistive technology adaptable into home environment is still essential.

As seen in two earlier descriptions, the reasons between why dressing up can be difficult for elder are alike why pushing a button can be difficult. These are factors to keep in mind along the whole product development process.

4.1.2 Define

Next step in product development process is to define the faced problem. In this part should also consider the borderlines of the project (Curedale 2016, 122-125; Ulrich &

Eppinger 2020). This phase is seen in flowchart Picture 10. Defining clarifies the challenges to achieve. This step forms framework within the development process.

Picture 10. Product development steps: Defining

Based on the results received from empathy phase, can be concluded that traditionally designed nurse call wristbands and necklaces are not meeting the needs of elderly. There is a need for more easily dressed cloth for upper body. Furthermore, there is a need for nurse call -button that does not require fine motoric skills as finger movement. In this product development the goal is to develop an upper body cloth that can be dressed on without moving arms and to add a nurse call –button to it which can be used without fine motoric skills.

To frame the goals and actions thesis writer did make limitations:

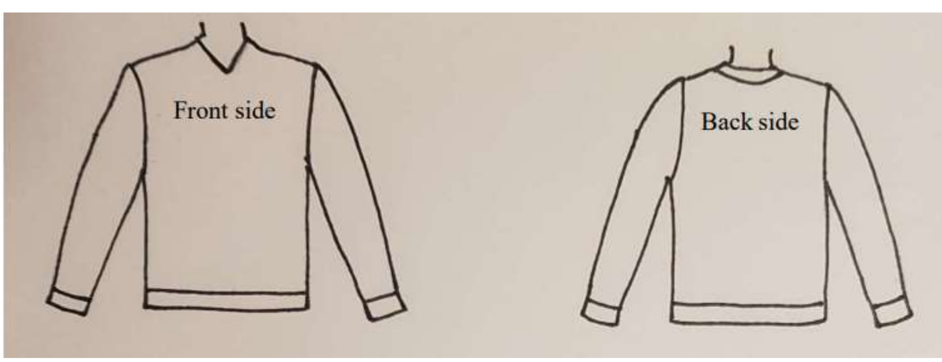
- Three first workshops that was arranged did only consider the design and its functionality.
- The Smart Jacket would not be dressed on elder: only the workshop participants would dress it on.
- The laboratory measurements were to proof functionality of chosen technology, there would be no measurements in elderly care unit.
- There will not be any mobile applications designed to make the Smart Jacket operative.

4.1.3 Ideate and prototype

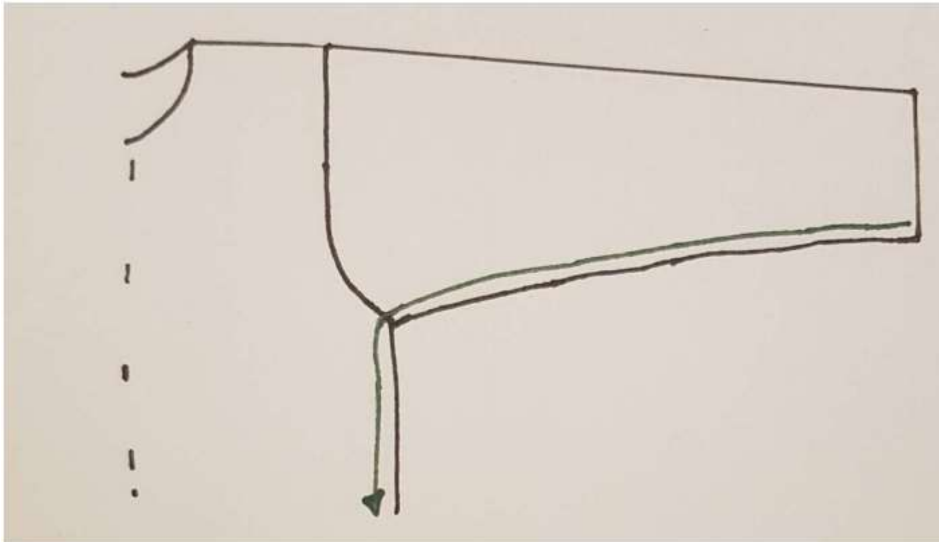
After defining the challenge met, thesis writer did inspect different kinds of clothing. For these purposes, hospital clothing, clothing for elderly and smart clothing were searched from Internet. Next following two steps were combined: ideating and prototyping, (Picture 11). Ideation phase is to find concepts to execute, and prototyping is when tangible prototype created.

Picture 11. Product development steps: Ideating and prototyping

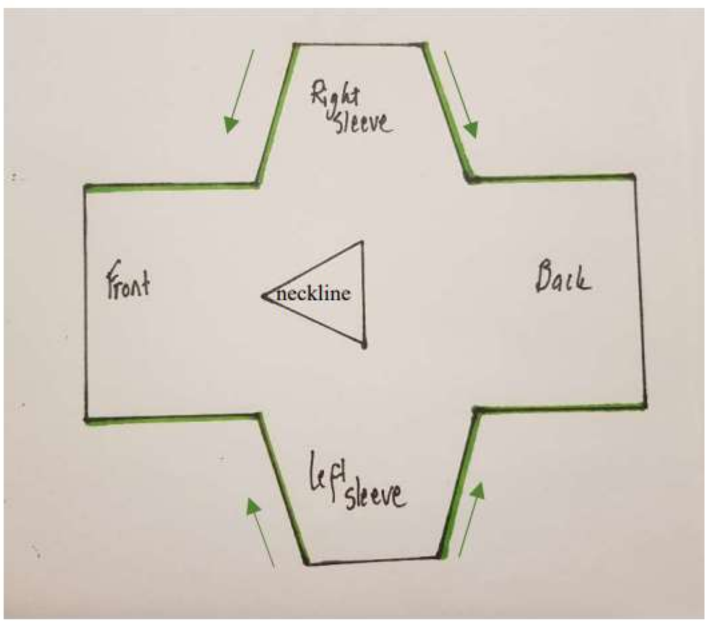
Thesis writer did sew the first prototype of smart jacket. The first version of cloth was a pullover (Picture 12.) purchased from flea market. To this pullover the thesis writer sewed zippers starting from cuff to waist (Picture 13). The zipper was joined with sleeve seam and side seam (Picture 14). Both sides were sewn alike. When the zippers were open, the pullover looked more like a poncho. The Dressing process would start with opening both zippers. After opening them, the head is supposed to go through the headline. The zippers would be closed when the sleeves are set were, they supposed to be. This first prototype was produced by writer of the thesis and design was based on the literature introduced before. The following matters were considered when making prototype 1: spasticity (NINDS, 2019), pain in joints (Bullbock et al. 2019); reduction of movements (Pantelaki, Maggi & Krotti, 2020) and perception of stigma (Li, Lee & Xu, 2020).



Picture 12. Pullover pattern picture



Picture 13. Modification number 1: Bedding the zipper into seams. Arrow is showing the direction when zipper is closing



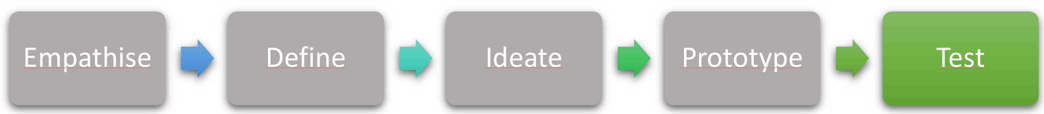
Picture 14. Pullover pattern picture from up.

In Picture 14 can be seen sleeve and side seams open, zippers marked with green color. Arrows show the closing direction.

After designing the first prototype Radio Frequency Identification was selected as used technology: Technology was chosen because it is relatively cheap, it can be applied to fabric, and it does not need any internal power source to work. RFID has shown already its potential in smart clothing applications. (Mehmood et al., 2020; Xiaochen, 2019.) RFID technology would be added later, but collaboration with University of Tampere already started by scheduling the meetings.

4.1.4 Test and prototype: The first workshop – functional design

After the first prototype was made it was time to test it (Picture 15). Testing was made in a form of a workshop. The first workshop was called: Workshop 1. - Functional Design. There were meant to gather more ideas how to improve the prototype1. Brainstorming was tool to gather ideas (website of University of Vaasa, 2018a)



Picture 15 Product development steps: testing

The first workshop was held Monday 4th of November afternoon (at 14:00-14:30) in 2019. At the workshop, there were five participants. The participants represented different specialties, but they all had knowledge of gerontology. The facilitator did open the workshop by welcoming everybody. The workshop rules were outspoken, and introduction of participants were held.

The first prototype version of the jacket was present so participants could touch it and test it on each other's. The facilitator did dress it on herself at first and told how it was meant to dress. The participants were active and tried several times to dress it up and seek ideas.

The workshop's goal was to ideate with brainstorming. The thesis writer thought that it would be important that the ideation phase was not guided in any direction. The participants role was to find features that could work on an elderly and features that could make dressing up easier. The data gathered from this workshop were taken in notes. For the anonymity reasons the comments and ideas were listed in upcoming order and they were not marked who said it. The comments are listed in appendix 1.

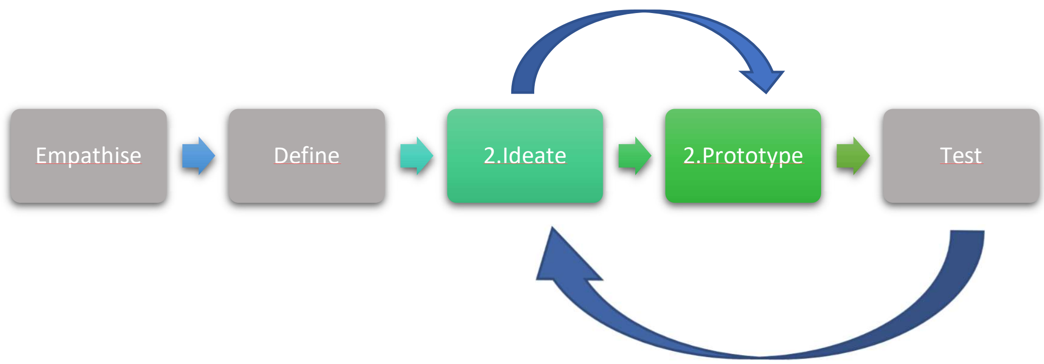
The information from the workshop were gathered and thesis writer started to make modifications to jacket based on the outcomes from the first workshop. The ideas and arguments are seen in Table 3.

Table 3. Ideas and thoughts from 1. Workshop (freely translated, APPENDIX 1 consist also Finnish)

Note	Important to sewing process	Important in general	Alterations made in next prototype
It is fine and exiting		X	
Is it difficult to wear/dress up?		X	
You have to pay attention if I want to connect (at the beginning) the zippers	X		X
-pretty handy		X	
- quite easy to close because it is the same long zipper.	X		X
- It is good that the zipper ends to hem. It makes possible to widen the hem area for needed extra space when sitting	X		
It is nice to dress it to person when the user sits.		X	
- the clothin is more fitted this way. Commonly: the tighter arm, the looser cloth	X		X
-Still it stucks if dressed arm with tight armpit	X		X
- Should the sleeve be closed? Is it easier that way, then we do not have to seek the beginning of the zipper.	X		X
-I would dress it in bed also		X	
- It is nice that the zippers do not show, like original pullover.	X		X
-Have to pay attention that skin does not get left between zipper.	X		X

The participants thoughts were categorized in three different columns to clarify the ideas *important to design evaluation, important feedback in general*, and *alterations made in next prototype* which were made in next prototype 2.

In product development process the process is not linear. After getting results from the first workshop thesis writer did step into ideating phase again (Picture 16). The ideation was based on information gathered from workshop 1 and thesis writer aimed keep the features important to customer.

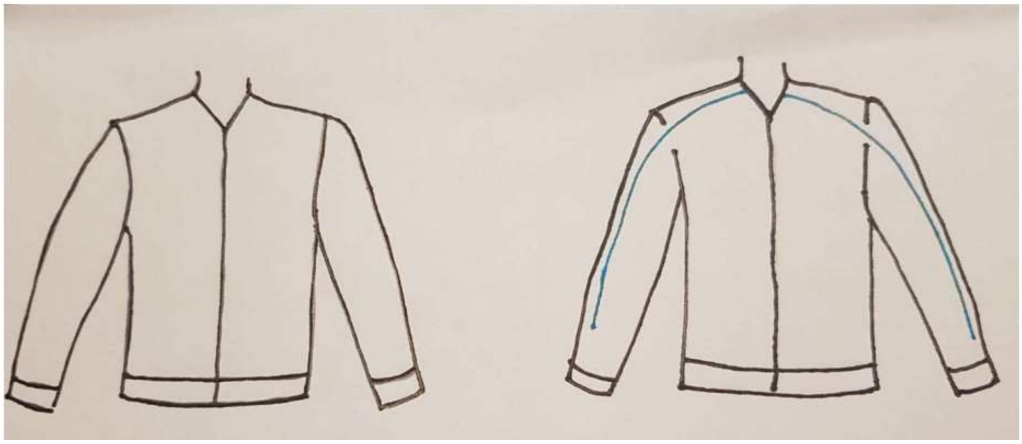


Picture 16. Product development step: second cycle

After second ideation phase the second prototype were made, picture 15. The general idea to design the zippers differently were something that thesis writer wanted to continue developing. One outcome from workshop were to keep the sleeve cuff closed. The alteration was made. One note was that if it was dressed up to elderly whose hand is tight towards the midline, the zipper might cause pressure to skin. Zipper would also be difficult to close and open if arm did not move at all from shoulder.

To search different solutions, writer did prototype 2 in a form of a jacket. This differs from pullover that did not have zipper in front. The assistive zippers on sleeves were relocated: To make closed cuff in order to make easier to close the zipper, the zipper start points were lifted 10 centimeters from cuff line: designed these ways, the cuff is whole. Presumable this enhances the dressability by making the closure of zipper easier. When the zippers were embedded to side and sleeve seam the found result from the first workshop was that severe reduction of shoulder joint movement might prevent closing the zipper. To remove the problem the assistive zippers were placed to proceed on top of the sleeve. The end of assistive zippers were at the neckline (Picture 17). For the more flowing zipping the writer selected a zipper with bigger teeth.

To keep the features found positive and useful, the writer did retain the two added zippers, making their color different than front zipper. The first prototype did get positive feedback about the zippers that did not show out. The writer did want to clarify if it did bother when showing and placing them apparent place. From the data gathered with first workshop, it seemed important to save the close-fitting style.



Picture 17. Pattern picture of prototype2. Added zippers marked with blue.

This jacket would be dressed on following way: firstly, the dresser would open the middle front zipper. Secondly the healthy arm would be slied into closed zipper. Thirdly the bodice would be brought from back to front under the armpit, then closing the front zipper. Last the spastic arm would be placed into sleeve and the sleeve zipper would be closed. To second workshop it was clear that the writer would ask opinions about the zipper and placing them, how would the jacket act when dressed up to elder that is in bed rest. This prototype 2 was ready to test in second workshop, Picture 18, as seen in picture the second test.

Picture 18. Product development steps: second cycle, testing

4.1.5 Test and prototype: The Second workshop – adjusting functionalities

The second workshop, called *Adjusting functionalities,* was arranged in the same care unit that the first one was. The workshop was held at Monday 18th November 2019 (14:15-14:45), to mention two weeks after the first workshop. There were four participants, three of them were present also at the first time. The participants represented different specialties, but they all had knowledge of gerontology.

The goal of the workshop was to find answers questions raised from the first workshop. (Are the zippers bothering when set on visible area? And is it dressable to person who is in bedrest?) Another important goal was to ideate improvements to prototype 2 and answer the question "*how could we make this better*?". To get more detailed and comprehensive dialog, the workshop was held in Finnish. The facilitator did open the workshop by welcoming everybody. The workshop rules were outspoken. The introduction of participants was held.

The second version of the jacket was present so participants could touch it and test it on each other's. The facilitator did dress it on herself at first and told how it was meant to dress. The thesis writer thought that it would be important that the ideation phase was not guided in any direction. The participants role was to find features that could work on a real patient and features that could make dressing up easier. The data gathered from this workshop were taken in notes. For the anonymity reasons the comments and ideas were listed in upcoming order and they were not marked who said it. The comments are listed in appendix 2.

The information (= data) from the workshop were gathered and thesis writer started to make modifications based on the outcomes from the second workshop. Thesis writer started to make modifications based on the outcomes from the second workshop. The ideas and arguments are seen in Table 4.

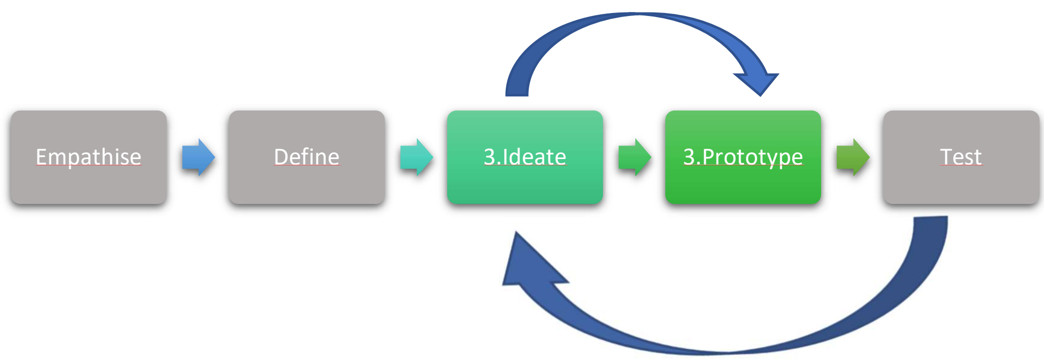
Table 4. Ideas and thoughts from 2. Workshop (freely translated, APPENDIX 2, consist of Finnish)

Note	Important to sewing process	Important in general	Alterations made to next prototype
- big zippers are better than small ones	X		X
- Zippers can be assembled visible area, in example blood pressure is easier to take with this jacket	X	X	X
-I have to pay attention what zippers I'm opening		X	
- It might be better if sleeves were open all the way. There is no need to open them allways	X		X

-Dressing up person in bed is really easy, it is almost as easy as hospital shirt that has open back		X	
-If I had to choose, I would take rather three zippers than one! The one in middle is also good.	X		X
- The color (of zippers) could be different: other color to sleeves and other color in the middle.	X		X

The participants thoughts were categorized in three different columns to clarify the ideas *important to design evaluation, Important feedback in general*, and *alterations made to next prototype* which were made in prototype 3.

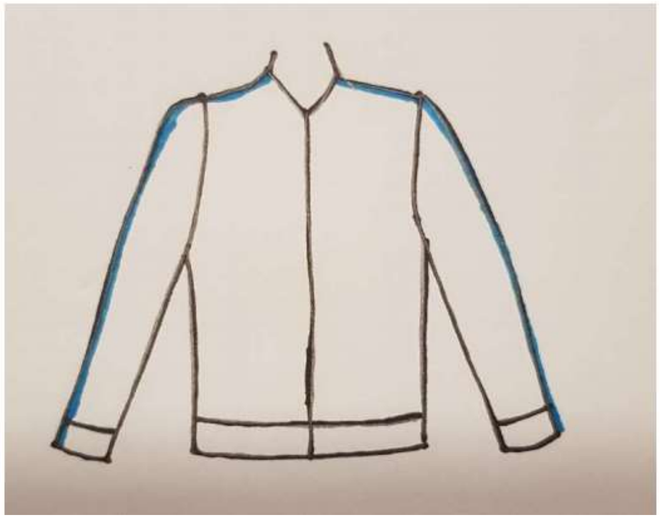
Starting the third cycle in development process took thesis writer back to ideation and prototyping phase. (Picture 19.)



Picture 19. Product development steps: third cycle, ideating and prototyping

The idea of having three zippers with color coding was important to save. It was clear that zipper with bigger tooth were brought to next prototype. To make some alterations, the writer decided to make again the cuffs as they were on the first try out: open. Coloring would also be coded: sleeve zippers would be different that the front zipper. This would be an action towards more simple dressing up process.

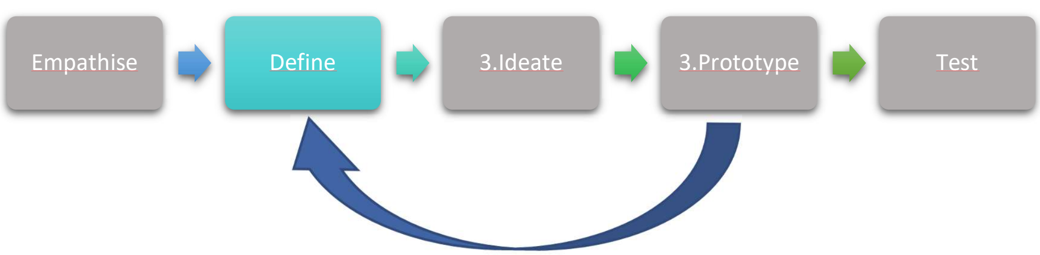
To make jacket a bit more basic, the writer did bring the zipper on the shoulder. It is now dividing the sleeve in half above the arm and continues its way to neckline crossing the shoulder (Picture 20).



Picture 20. Pattern picture of prototype 3. Blue color is marking the zippers.

Blue color is marking the zippers. This jacket would be dressed on following way: firstly, the dresser would open the middle front zipper. Secondly the healthy arm would be slied into closed zipper. Thirdly the bodice would be brought from back to front under the armpit, then closing the front zipper. Last the spastic arm would be placed into sleeve and the sleeve zipper would be closed. The product development and thesis project did have its delays due the unpredictable situation of COVID19. The virus did cause restrictions in meetings, and it closed all the public spaces. It did force people to work in distance. In health care the workload did create massive crisis also and the workload of the thesis writer was unbearable. The thesis continued its pact in the fall semester 2020.

After designing the prototype 3, thesis writer did step into defining again. This time it was for the nurse call -button. (Picture 21)



Picture 21. Product development process: Defining

4.1.6 Laboratory validation Study

To get deeper understanding of the RFID operations and their potential in smart jacket. Sari Merilampi (Adjunct professor, D.Sc Tech, M.Sc Tech) in Satakunta University of applied sciences and thesis supervisor did help arrange a meeting with Johanna Virkki, Academy Research Fellow, Faculty of Medicine and Health Technology from Tampere University of Technology. The meeting was brief but informative. With Virkki the thesis writer did discuss about expectations how the nurse call button should work and how it would be done technically considering approximate distance, used materials, location possibilities and person using it.

To conclude the meetings results: thesis writer would be assisted to attach the UHF passive RFID tag (shown in Picture 22) on jacket under development. Tag consists of the micro circuits and antenna. The power source of this technology is external. The antenna would be 20cm long and it was made from conductive fabric. The exact location was decided at the second meeting 22nd September 2020. According Seideman et al. (2009) passive UHF RFID did not to cause any disruption on medical devices

The tag's functionality is simple: By covering the antennas circle part for 3 seconds, radio wave to reader is blocked and the reader sends notification to nurse that user (the elder) in jacket needs help. According to Landaluce et al. (2020) to make the concept work, external reader and I.e. Mobile application is needed. These RFID tag, reader, and mobile application works in WSN (wireless sensor network).

Picture 22. UHF passive RFID tag

At this meeting, the tag was not yet to glue on. And due COVID19 the Universities continued working distant two days before scheduled meeting. The tag waited it’s time to 22nd September to get attached to jacket.

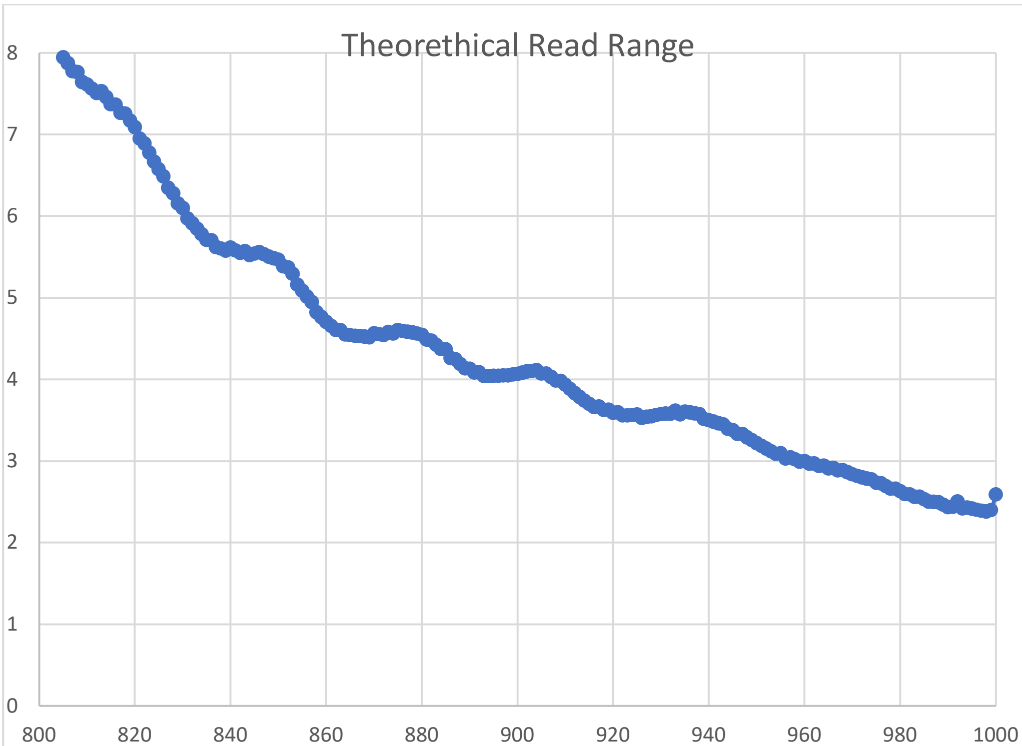
Tuesday 22nd of September the RFID tag was attached with glue onto jacket at Tampere University at the hub of science and technology. Johanna Virkki and Adnan Mehmood (doctoral researcher) as specialists did execute the procedure of attaching the antenna. The antenna decided to locate on Smart jacket nearby heart because it is a place that allows the covering with either of hands. The used fabric was called Shield it Super. Fabric was stretching, washable and conductive. (website of lessemf 2020).

As product development process, at this Tuesday did include defining as last decision to attach passive UHF RFID tag. The professionals did ideate the location to tag, being in the middle line of human body and nearby middle line of the body. The prototype 4 was made when doctoral researcher Mehmood did attach the tag on the jacket. Laboratory tests were taken.

To exploit RFID tag as nurse call –button the proof-of-concept study was conducted. The proof-of-concept study aims to actualize uncertain idea (National Science Foundation 2014). The important questions that tests would answer was: does RFID technology work on Smart Jacket? Does the blockage of radio frequency signal work? How far the signal is carrying in other words how long is read range? This information is needed because it is the measure how far the responder can carry the power to activate the attached tag, or specifically, microchip on it (Bensky 2019).

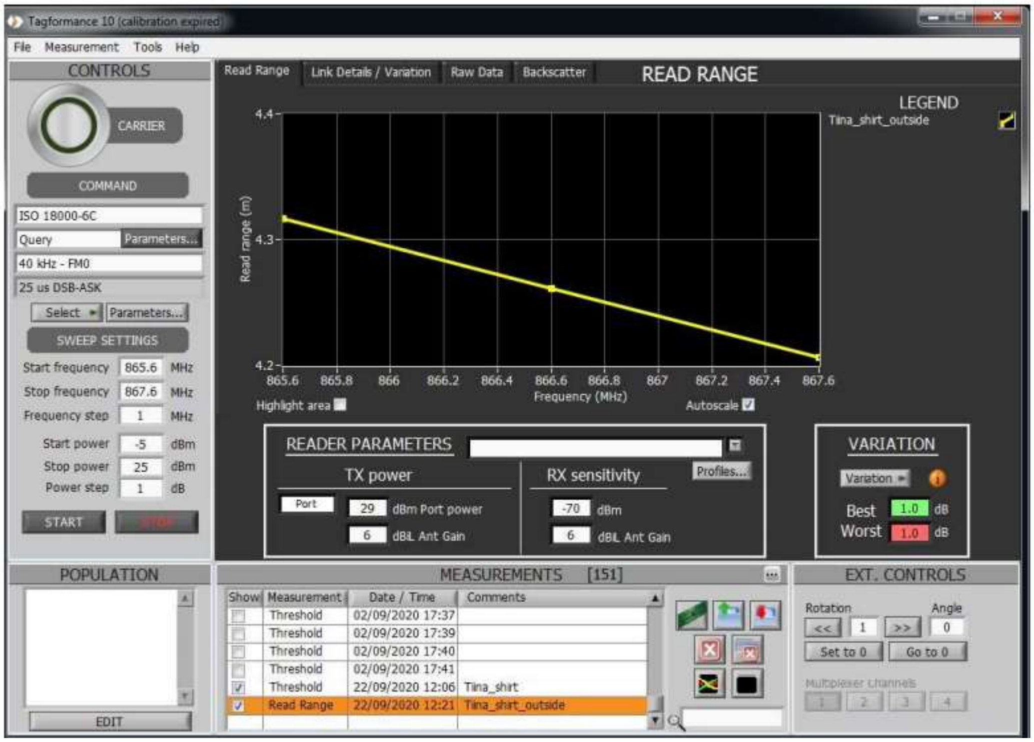
If the RFID technology worked, it was attached rightly on Smart Jacket. If the connection between the reader (with power source) can be broken, the idea of this thesis’ nurse call –button could be workable technology as alarm system. The information about read range is important to evaluate is this technology adaptable in indoor environments, I.e. care units for elderly.

Frist the tag was tested in radio frequency anechoic chamber. In Picture 23 is seen theoretical read range of jacket and the reader. The used frequency varied between 800-1000MHz and in undistracted conditions read range was up to 8,4 meters at frequency of 800MHz. However, the operation frequency of such systems in Europe is 865 to 868 MHz. On this frequency theoretical read range in Radio Frequency anechoic chamber was 4,6 meters. As rising the frequency towards 1000 MHz the reading distance did reduce in 2,382 m in lowest (in 998MHz). As Bouhassoune et al. (2020) informs the noise coming from body tissues, has impact on read range.



Picture 23 Theoretical Read Range

Next step was to measure jacket on person. The picture following (Picture 24) describes that in distracted conditions the longest (4,3m) read range were achieved in 865,6 MHz. The maximum distance on person was 4,3 meters giving sight how the readers (with power source) should be assembled, if the Smart Jacket was put in indoor environment with used tag, reader and used frequency. The result 4,3 meters is directional and do not exclusive the possibility of adapting Smart Jacket in indoor environment, such as care units for elderly. The reduction of read range is caused by the noise from human body, items, and materials in laboratory (Bouhassoune et al. 2020; Lehpamer 2012).



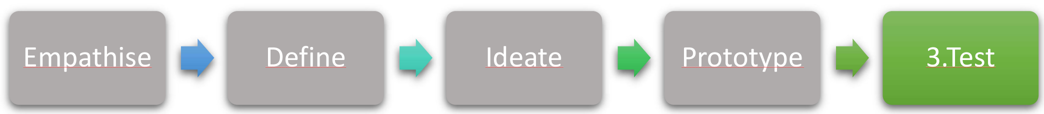
Picture 24. Parameters of jacket's read range on person

This laboratory day did include design thinking steps (Picture 25): empathizing, defining, ideating, prototyping and test phases: with empathizing the location of tag was ideated; then the location was decided based on size of antenna and based on information of upper limb movement limitations and lastly the laboratory tests were made with prototype 4.

Picture 25. Product development steps: empathizing, defining, ideating, prototyping and testing.

4.1.7 Test: The third workshop – ideas in practical use

Due the COVID19 third workshop, called Ideas in practical use, was arranged informally. The workshop was arranged during a workday kind of nonstop – feedback gathering allowed. The tangible prototype 4 was present to be tested (Picture 26) and the participants did get a chance to test it on another person. There were four participants and they represented different professions, but they all had knowledge on gerontology. This time white board were used information gathering. The workshop was arranged 24th September 2020.



Picture 26. Product development steps: third cycle test in laboratory conditions

Data The information from the workshop were gathered and thesis writer did start to plan modifications to jacket based on earlier workshops. The ideas and arguments are presented in Table 5.

Table 5. Ideas and thoughts from 3. workshop (freely translated, APPENDIX 3 consist of Finnish)

Note	Important to sewing proces	Important in general	Alterations
Blood pressure and blood sample are taken easily		X	
Central vena catheter is used more easily		X	
Easy to dress		X	
I like the design, it does not look like hospital cloth		X	
- Nurse call -button could be assembled on bicep. Is it removable?	X		
-big zippers are good thing	X		
- sleeves are spacious, good.	X		

The participants thoughts were categorized in four different columns to clarify the ideas important to design evaluation, Important feedback in general, not relevant in this context and alterations.

This workshop data was concerning feedback and ideas how benefit the jacket, so for writer this was a sign to end the project loop here. There were no more modifications into jacket done. The information from this workshop were useful: the participants thought that this would be useful when dressing up elder; participants did argument that it would be easier to take blood pressure and check central vena catheter using the sleeve zippers. They affirmed the previous workshops feedback that bigger teeth in zippers are better, and it is nice to have some clothing that do not straight away look like a hospital clothing.

4.1.8 Ideate: Smart clothing workshop for future innovations

On November 9-13th 2020 Satakunta University of applied sciences did organize digital Welfare technology fair. There were scheduled a workshop concerning smart furniture and smart clothing, the thesis writer did take part in among other participants. The thesis writer got an opportunity to gather ideas how to enhance the jacket: what would be the next improvement. The introduction how the jacket works were made using the Teams platform via video connection. There were 47 participants in the workshop. The information was gathered using Padled a digital ideation platform. The results are in appendix 4 and it contains ideas also to smart furniture part. In table 6 are gathered only the smart clothing ideas. Participants of this workshop were representing different fields of professionals and the skills and specialties of the participants were collected with Mentimeter – digital ideation platform. The results are in appendix 5. Both Padlet and Mentimeter allows adding content with anonymity secured. The information of this workshop was utilized as follow-up research ideas.

These results are categorized in three different columns by the type of effect wished: innovations that concerned device to track something or someone. Also, in this column is seen innovations that tracker bodily functions or weather conditions. In second column is marked the innovations that are wished to cause impact. Impact means in this context impact on the person using the product or i.e., impact on environmental matters. Third column are for the innovations that are to alarm and warn the user. In this column is seen ideas that sends i.e. notifications to user or third party to prevent accidents or damage.

Table 6 Smart clothing workshop at Satakunta University

Note	To Track	To Impact	To Alarm
A piece of clothing that can warm a certain spot, for example an ailing shoulder can be warmed up with a shirt		X	
Pajamas, sheets that monitor your sleep quality, breathing etc.	X		
Control of the lighting and temperature with RFID tag clothing. So when you come home, you have perfect lightning and temperature. I think it is available with NFC now (Samsung maybe?).		X	
Lights can be turned off with antenna. (jacket)		X	
Rehabilitation game, antennas everywhere		X	
Monitoring the amount of activity, reminders on that matter	X		X
Clothing that prevents people suffering from dementia escaping from their home and get lost			X
Temperature sensor to senior underweight outside	X		
Blood pressure monitor (If this can be done as it is difficult without novel sensor)	X		
Posture tracker	X		
HR monitoring in clothing. You could combine the technique from FirstBeat and measure the balance of rest and work more comfortably.	X		
The message clothing. T-shirt with the display like e-ink that can show messages to other people.			X
Hat that becomes a helmet if person falls and hits their head		X	
Fall monitoring	X		
accelometers	X		
Jacket could send message when crossing the fence (for safety)			X
Shoes with sole sensors for monitoring walking patterns/ gaits/abilities/movement activities for the elderly and with gps tracker	X		
Activation of people sitting their job – a chair could ask to take a break to play shoulder activation game with smart office wear		X	
Smart clothing for relieving back pain		X	
Shirt for sports, team players to measure heartbeat, speed, km/hr, physical activity	X		
When you have RFID reader in a phone, you could also use your outdoors clothing for controlling your phone.		X	
Persons in covid-quarantine would be flashing a red light on their head			X
RFID-tag reader on your workplace door. In my workplace we have physical tags to track our working time but if it was sewn in our clothing/or have a bracelet we always would have accurate readings	X		
You could say hi by tapping your shirt		X	
Clothing that can measure your calories you have used during a workout or some kind of other physical activities	X		
Safety clothes -gives a sing if you need help (outside) -turns on “light” when it gets dark		X	
Clothing integrated vital information about epilepsy or other condition			X
Tracking locations	X		
If it rains, open automatically an umbrella		X	
Socks that have easy put on interior		X	

4.2 Conclusion of results

The new way of placing zippers found to be beneficial when dressing spastic elderlies: with Smart Jacket elder can be dressed without moving user's arms at all and limitations can occur in both sides. The nurse call- button passive UHF RFID technology was adopted. The tag attached to Smart Jacket was made from conductive fabric and microchips making it completely functional without any power source attached on Smart Jacket. The conductive fabric is washable. (website of lessemf 2020) so adding tag on Smart Jacket does not prevent washing it.

The laboratory tests show that RFID technology can be added successfully on Smart Jacket and the concept of blocking radio wave with hand making the notification is possible. The Smart Jacket was tested undistracted conditions, in unechoing chamber, making the reading rage achieve maximum of 4,6 meters. When measured on person, naturally the range did shorten in 4,3 meters due EMI. Tested ranges were achieved in legal band allocation in Finland (865-868MHz). The on-person-measurement is similar to Yang et al (2019) findings.

The workshop arranged for future studies yield wide variation of ideas concerning Smart Clothing. The ideas are categorized and summarized in three columns: to track, to impact and to alarm. Lot of ideas in future studies did rise from that workshop.

The second aim of this thesis was to describe the best practice of multidisciplinary collaboration. This thesis description of process is one way emphasizing the outcome. The best practice of multidisciplinary collaboration is compressed on following:

- design thinking process has proven assets (Altman et al. 2018)
- using all the professional resources available is major asset
- try to minimize preconception and
- respect the knowledge of others

These are findings the thesis writer did along the process. Design thinking is agile way to develop iteratively products (Altman et al. 2018). Without the help of all stakeholders the Smart Jacket would be different outcome. To all in creative processes it is important to minimize preconceptions and have the respect of other (Franko et al. 2017). This prototyping of smart jacket design did concretize the importance of recognized preconception: the design of having three zippers on one jacket is unforeseen but let to the outcome wished. Respect is something that should be always considered when working co-operating multiprofessional, the respect towards different professionals and their knowledge lead into creating the Smart Jacket.

5 RELIABILITY AND VALIDITY

This thesis is product development process, and it differs from traditional research methods. Also, the reliability and validity are evaluated in different manners. The validity of thesis consists of detailed description of thesis process, transparency and logical, justified choices made during this process.

There are three kinds of replicability: exact replication, empirical replication and conceptual replication (Polit & Beck 2010; Aguinis & Solarino 2019.). This thesis can be replicated, but end result might vary. The product development process on other participants and professional stakeholders might have different kind of end result. Exact replication of this thesis is impossible for the uniqueness of product development and the ideas concluded cannot be undone. The empirical replication can be done, meaning that this thesis' choices of actions can be proceed and include different participants and professionals. The end result might have same features that in this thesis, but it is more likely to differ. This study could be replicated conceptually: if the approach were explorative; had case study elements the end result might align with this thesis.

The outcomes from this thesis were partially unpredictable: thesis writer did not know what kind of end result product development would generate. The aims of this thesis were achieved. The journey of product development path follows through logically and the theory frame supports the choices of actions. The laboratory study did have the similar results as the previous study of the same topic. (Yang et al. 2019.)

To get more direct user information, thesis writer should have included the elderly into workshop participants. To reassure group that is vulnerable (the elderly) is safe, thesis writer decided to outline elderly from this thesis. In other hand design workshops did consist of people active in elderly care and familiar to elderly daily challenges. Those who was included to workshops did dress up elderly daily. The workshops were multiprofessional to get more collaborated information. The method before is called expert evaluation. In innovative development expert evaluation is feasible method to evaluate the improvement of selected matter. Expert evaluation is cheap, agile and offers similar outcomes as target group (the users). (Marinchenko 2019.)

Participants in design workshops did not have any known bias. They did not have any consequences after participating and they were voluntary. Anonymity is secured by not publishing any names or workplaces of participants.

Transparency in research is important part of trustworthiness (Aguinis & Solarino 2019). To add transparency, it is described in thesis what alterations were made and what did get left out. Transparency is tried to increase with publishing all the arguments in brainstorming. Turned out the information from workshop did add the understanding the need for this kind of product in markets.

In product development process it is impossible to predict the outcome when making decisions based on gotten results. As the defining challenges were perceived complicated, it has effect on gotten results and content of them. Thesis writer notes that the results are supporting the choices of methods and the journey of product development is justified with reflected decisions. At the end, the selected and carefully framed challenges were achieved. This thesis experimental part (the product development part) is chronologically described.

Pragmatic writing was needed in action part of the thesis. Product development process is described, and pictures was used to support the text. The core findings were analyzed, and thesis writer chose to include findings in the same paragraph with product development process. The data from RFID measurements were analyzed separately from the jacket design workshops and the smart clothing workshop. The last mentioned did have different agenda than the earlier workshops so the data from there were differently handled and analyzed.

To evaluate reliability, thesis writer notes that chosen protocol was reasoned and described. The results and outcomes from this thesis are unique. This thesis was a chance to create something practical and answer the need of work life. This thesis design workshop participants were present in ordinary life of the actual customer (the elderly being the target group) and in a way these participants were *the users* also. Selecting these representatives into workshop adds reliability of this thesis.

5.1 Ethics

Ethical values are honesty, accuracy, and caution. The researcher is always responsible of ethics of research. Ethical thinking is needed when evaluating a conducted research. Referring accurately and selecting carefully the used resources belongs in ethically well thought research. (Website of University of Jyväskylä.) The ethical recommendations for thesis writing at universities of applied sciences set the guidelines of writing thesis ethically approved. (Lempinen & Raivo, 2019, 7.) Finnish legislation guides ethical principles of research. There are said that human dignity and self-determination should always be protected, cultural legacy should be respected, and no harm should be caused in any stages of research. (Finnish constitutional law 1999/731, §6–23; Tutkimuseettinen neuvottelukunta, 2019.)

Thesis writer did ethical choices throughout the thesis process. Thesis writer did respect the Finnish constitutional law and followed the regulations set by Finnish National Board on research integrity (Tutkimuseettinen neuvottelukunta, 2019). To guard those who are vulnerable, thesis writer did exclude elderly from this thesis. Anonymity was guarded and no names of participants in workshops were gathered. Participating on this process was voluntary.

As RFID technology in health care should be implemented with caution, in this thesis is the ethical dimension noted: the laboratory measurements were made in ranges legal in Finland. Information security is continuous challenge that RFID developers must be aware of. Patient data should be handled with caution and there are no room for risk where customers health is put in danger. Luckily, encryption is continuously advanced. (Fernández-Caramés et al., 2017; Mansoor et al., 2019.)

Although the RFID technology is well researched, the scientific articles that were appropriate to this context were challenging to find. Most of them were purely studies to technological research; they lacked the health care and design angles. Additionally hey were mostly chargeable and thesis writer did decision to include only articles that were available (i.e. from databases or libraries). The scientific articles concerning RFID challenges in health care were relatively old and it is important to be aware of.

6 DISCUSSION AND CONCLUSION

The aim of this thesis was to develop upper body cloth for elderly that has easily pushed nurse call -button and is dressable despite the physical limitations that elderly might have. The other aim was to describe the best practice of multidisciplinary development process and collaboration. The set aims are achieved. The elderly's challenges concerning dressing situations might have impacts on perceived quality of life and could be one reason to move in elderly care. As Ministry of social affairs and health (2020) pursue, the support should direct to home of elder and new innovations are still called for.

The solutions and devices that assists elderly living should be based on the understanding of elderly life. To get information vital in development process it was reasoned to include professionals in elderly care within design process. (Nauha, et al. 2018) As presented in theory part the barriers elderly adopting new technologies are: the size of output screens are often too small; perceived limitations in abilities to use or understand device and stigmatizing appearance of device (Farivar, Abouzahra and Ghasemaghaei, 2020: Li, Lee & Xu, 2020). The Smart Jacket nurse call -button is easy to use and it does not require any fine motoric skills. The Smart Jacket is operative with minimal physical effort. These two factors are making the product few steps closer to accessible design (website of NDA, 2020).

This Smart Jacket was designed for elderly, but the design is not bound to age: the jacket could be beneficial for those who have limitations in upper body movements regardless the age of the user. The design of the jacket could advantage in hospital: Multiple treatments are operated nearby upper body or upper limb, some of procedures are limiting the normal use of hand. In example the following: Central Vena Catheter works nearby collarbone; dialysis catheter can be placed on upper arm; blood pressure measurements and blood samples (arteria or vena) are taken from arm. (WHO 2010; NHS 2018; Kolikof et al. 2020; Sosteri, 2020). From the thesis writers experience of practical work, often cloths complicate executing the treatments. With this Jacket design the actions in procedures could be more fluent if cloth could be removed easily from area that is getting the treatments. For some people the jacket design could seem desirable for its unoriginal appearance, the assistive zippers could be seen as design element without operational function. The assistive devices might stigmatize (Li, Lee & Xu, 2020) and thesis writer did want to create cloth that is wearable to all.

As in thesis challenges were set the goal of describing the best practices of multidisciplinary development process, the concluded outcomes support the theory part. The best practice includes agility, cooperation, and creativity (Deuff & Cosquer, 2013; Curedale, 2016; Franko et al., 2017; Tomitsch, et al., 2018; Dam & Siang, 2020). Especially collaboration of different professionals turned out to be fruitful. This thesis was concrete example of the design thinking process and as proceeding it the writer had insight how major meaning the iterative development has. Within limited time there is chance to improve the product quite lot. Design thinking is used in health care inconsistently, but it might offer an alternative to traditional research methods (Altman et al. 2018).
There are lot of scientific research done concerning the RFID technology in health care use (Van der Togt 2008; Seideman 2009; Rahman, Bhuivan & Ahamed, 2017; Zhu et al. 2017; Lin et al 2018: Yang et al. 2019; Bouhassoune et al., 2020). The passive UHF RFID is feasible in clothing (Mehmood et al. 2020) and in writers' opinion with multiprofessional development the technical solutions are expected to be efficient, functional, and durable.

The Smart Jacket concept with RFID tag has multiple opportunities to be deployed in use. In this thesis the idea was to create alarm by covering the tag with hand. This procedure can be changed to have different outcomes with software. Only imagination is the limit when thinking the ways to apply the technology. In example it could be adapted in patient surveillance by creating an environment that covers the read range as Yang et al. (2019) did. In differ to Yang et al. (2019) the user leaves the room, connection of tag and reader breaks and notification is sent to nurse's phone. (Yang et al. 2019 did use different kind of sensor and information was gathered with censoring tags to track the movements.)

Thesis writer has lot of ideas how to benefit this technology on other usage: The information load in health care is heavy and lot of information is difficult to remember or achieve when necessary. This RFID tag could be used in elderly care to share information accurately. The RFID tag could be attached i.e., on door of the elderly room and by covering the tag, it would send notification to mobile phone and tell what is essential when cared for elder in that room. I.e. it would tell if the elder needs rollator to walk with or has hearing implants that nurse has to assist to put on elder's ears. This would optimize the work process and cut of the seeking the needed information from patient records in office.

If used as assistive technology in daily life the RFID tag attached on shirt could assist to speak as ideated in last workshop held. By covering the tag on shirt, it would help the user say i.e., "Hello" with programmed mobile application. The tags can sense environmental changes and could be used as assistive tool helping decision making: Children that have difficulties with executive functions might find helpful if the RFID tag on shirt did sense coldness and guided (via mobile application) when going outside "It is cold, please dress the winter jacket on". The writer finds intriguing the idea of assembling the RFID connection between the user and i.e. busses. The Smart Jacket would help to pick up the right buss, so when the buss needed is near it sends notification to users' phone and announce that the right buss is coming. This might help i.e., the blind people.

Asset to work life is practical. Dressing elder up might be easier with Smart Jacket and it offers an alternative to wristbands and bracelets. If implemented in bigger ecosystem of patient surveillance, it might increase perceived feeling of safety; it might also reduce the timeline between needing help and receiving it because the button might be easier and quicker to activate than i.e. the original alarm buttons. The elder does not have to adapt and reach for the button, because it is so near located. It might also lighten the dressing up situations for both parties. Often care professionals perceive the dressing up stressful due the presume of causing pain to elder, and elder might remember the possible pain caused earlier situations. If the Jacket adapts to elder, elder does not have to adapt to cloth and presumable the pain would not increase during dressing up.

If the Smart Jacket were part of the patient surveillance, it might affect the quality of care. If care professional can trust that the alarm is pushed accurately the unnecessary visits are reduced. It might increase intentional communication between nurse and elder if no other options are fitted to elder. If the technology was profitable in home use, it might help elder to live home longer and delay moving into assistive care.

The global situation of COVID19 did set an unpredictable challenge limiting the care professional availability, luckily there were enough useful data beneficial to development process. The nature of thesis, development of a product, changes the report structure of thesis and thesis writer did find challenging to form the optimal structure of this thesis. Thesis writer acknowledges the limitations in this Smart Jacket nurse call -button concept: the attached antenna is located nearby heart but also intimate part of body, especially to women. That would be corrected on future designs. Also, the next development aspect would be that the jacket would be easy to wear with out other person's help. To keep in mind the elderly as user group, this design might be too difficult to wear due presumable reduction in cognition and arm movements. It is also questionable if the elder with memory loss, can learn the unusual way to make alarm. As earlier mentioned, the collaboration of Satakunta University, Tampere University of Technology and elderly care professionals turned out to be productive. And to thesis writer, extremely teaching. Thesis writer did practice cooperative, communication, facilitator, and argumentation skills. Also, the information retrieval, reporting and English skills were enhanced.

6.1 Conclusion

This thesis was a multidisciplinary development of Smart Jacket for senior care. The Smart Jacket is device that has personal alarm system that utilizes wireless sensor network with RFID technology. The study consisted of three design workshops to get user centered information about dressability and a laboratory testing to proof the concept operative. The descriptive part of thesis was to emphasize the best practices of collaboration in product development process.

Based on the outcomes of the thesis, the writer concludes the following:

- Passive UHF RFID can be added on clothing.
- Passive UHF RFID technology has potential to be used as personal alarm system in elderly care.
- There is need for unrevealed clothing that are more accessible to all.
- Multidisciplinary collaboration creates productive outcomes exploit in practical use.

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APPENDIX 1

The first workshop (Mon 4th Nov 2019) comments

- Hieno ja jännittävä
- onko vaikea pukea
- tarvii tarkkuutta että saa tän vetskan pujotettua
- aika kätsy
- joo aika helppo viedä kiinni kun on samaa vetoketjua
- Hyvä kun tohon helmaan tulee tuo vetoketjun kelkka, tulee tilaa istujalle
- Kiva pukea istuessa
- Tällä saa tyköistuvuutta. Yleensä, mitä tiukempi käsi sitä löysempi vaate
- Vähän kyllä silti kinnaa, jos pukee tiukkaa kainaloa
- Pitäskö jättää hiha kiinni, olisko helpompi sit pukee? Ei tarttis etsiä noita päitä?
- Kyllä mä pukisin tän ihan sänkyynkin
- Kiva kun nuo vetskat ei näy! Ihan ku olis tavan paita
- Totta!
- Pitää muuten varoa ettei iho jää väliin
- Seuraavaksi sitten housut samaan settiin

Note	Important to sewing process	Important in general	Alterations made
It is fine and exiting		X	
Is it difficult to wear/dress up?		X	
You have to pay attention if I want to connect (at the beginning) the zippers	X		X
-pretty handy		X	
- quite easy to close because it is the same long zipper.	X		X
- It is good that the zipper ends to hem. It makes possible to wide the hem area for needed extra space when sitting	X		
It is nice to dress it to person when the user sits.		X	
- the clothin is more fitted this way. Commonly: the tighter arm, the looser cloth	X		X
-Still it stucks if dressed arm with tight armpit	X		X
- Should the sleeve be closed? Is it easier that way, then we do not have to seek the beginning of the zipper.	X		X
-I would dress it in bed also		X	
- It is nice that the zippers does not show, like original pullover.	X		X
-Have to pay attention that skin does not get left between zipper.	X		X

The second workshop (Mon 18th Nov 2019) comments. With yellow the alterations/modifications

- On paremmat vetoketjut kun on isot hampaat
- Ei haittaa jos on näkyvällä paikalla, on jopa helpompi vaikka ottaa verenpaine
- Tässähän pitää miettiä mitä aukoo
- Voisi olla parempi jos ne hihat olis auki, ei tarvi välttämättä kokonaan aina aukoa
- Sängyssä pukeminen on tosi helppoa, menee melkein samaan kuin avopaita
- Jos pitää valita niin kyllä mielummin otan kolme vetoketjua kuin yhden! Tuo keskimmäinen vetska on myös todella hyvä
- Värit voisi säilyttää erillisinä: hihoihin yhden väriset ja keskelle eteen sitten toinen

Note	Important to sewing process	Important in general	Alterations
- big zippers are better than small ones	X		X
- Zippers can be assembled visible area, in example blood pressure is easier to take with this jacket	X	X	X
-I have to pay attention what zippers I'm opening		X	
- It might be better if sleeves were open all the way. There is no need to open them allways	X		X
-Dressing up person in bed is really easy, it is almost as easy as hospital shirt that has open back		X	
-If I had to choose, I would take rather three zippers than one! The one in middle is also really good.	X		X
- The color (of zippers) could be different: other color to sleeves and other color in the middle.	X		X

APPENDIX3

The third workshop (24th Sept 2020) comments

-saa otettua RR helposti
- ja CVK
-helppo pukea, heti käyttöön
-tykkään designista, ei sairaalavaate lainkaan
- hälyttimen voisi laittaa hauiksen kohdalle. Voisiko olla siirreltävissä?
-isot vetskat on hyvä juttu
-tilaa hihoissa on hyvä!
Translated version

Note	Important to sewing proces	Important in general	Alterations
Blood pressure and blood sample are taken easily		X	
Central vena cathether is used more easily		X	
Easy to dress		X	
I like the design, it does not look like hospital cloth		X	
- Nurse call -button could be assembled on bicep. Is it removable?	X		
-big zippers are good thing	X		
- sleeves are spacious, good.	X		

APPENDIX4

Padled answers, 13th Nov 2020

APPENDIX5

Skills participants had in Smart Clothing workshop