BACHELOR THESIS CREATIVE TECHNOLOGY

Research and conceptual design of a new user-driven fall detection concept for older adults

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Abstract

Fall accidents in the elderly are an underestimated and growing problem. Due to a fast aging population, the number of serious fall accidents increases sharply. In many cases, a fall in old age has far-reaching consequences for the lives of the elderly and leads to increasing pressure on both formal and informal care. Therefore, the aim of this study is the design of an innovative user-driven fall detection concept for frail older adults and their carers. Literature and State-of-the-Art research showed that many fall-detection devices are currently available, but there are still many improvements / opportunities for a product that meets the needs and wishes of the elderly. To find out exactly what the needs and wishes are, various interviews and surveys were conducted. A brainstorm on ways to capture as many needs of stakeholders as possible in one product was conducted. The proposed product concept consists of modular wearable device for the elderly and a corresponding smartphone app, which will be used by a group of carers. The wearable device can send an alarm to the carers in the smartphone app in the following three cases: an automatic fall alarm, a personal alarm and an emergency push alarm. In case of an alarm, the carers are warned by the smartphone app which goes into alarm mode. From a list in which the group of carers are ranked, the app determines who should be automatically asked to provide immediate assistance first. This concept was developed based on the requirements of the different stakeholders using an exploratory design approach and by using several idea generation methods. A digital product model of the wearable device and an interactive mockup of the smartphone app were created to test and evaluate the product concept with key stakeholders. The product has additional features and services that not exist in the currently available fall detection systems. Therefore this new product has the potential to become a success, but a physical technical realization will be required to further test and evaluate the product concept.

Acknowledgement

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Finally, I would like to thank the representatives of the different stakeholders. In particular I would like to thank all people who participated in the interviews and surveys for their feedback which was very useful in the process of designing of a product which hopefully will improve the quality of life of the frail elderly in the future.

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CH 1_Introduction

1.1 Current situation

One of the biggest challenges for (the future of) healthcare is the growing number of older people. According to the population forecast of the CBS, the share of the over-75s will increase from nearly 8% of the population in 2017 to nearly 12% in 2030. In 2030, there will be more than 2 million people over 75 in the Netherlands. [1]

In addition, life expectancy is increasing: in 2018, a 75-year-old man has an average of twelve years to live and a 75-year-old woman has fourteen years. By 2030, both men and women will have on average one year longer to live. [1], [2] Due to these two facts, there is 'double societal aging' in the Netherlands. [3] 92% of the over-75s currently live independently, and two-thirds of the over-90s still live independently. In 1980, 63% of the over-75s lived in a care or nursing home, in 2010 this was 14%, now it is about 11% and in the near future this will stabilize to between 5% to 6%. [4] There are several reasons for the elderly living at home independently for longer.

One of the main reasons are the severe cutbacks in care for the elderly during the crisis years around 2008, as a result of which many people who work in the care of the elderly lost their jobs and ultimately many care homes were closed. [5] In that period, government policy was to encourage older people to live independently for longer. [6] As a result, older people in general have started to think more negatively about living in a care institution. [1] The figures also reflect the fact that older people increasingly want to keep their own control over their lives and they have more opportunities to do so than before. An important reason for this is that the elderly are increasingly healthy until older age; life expectancy without restrictions increases. Nowadays older people do also have the financial means to live independently. [6]

1.2 Problem statement

As elderly people increasingly live at home independently up to old age, the pressure on informal care and community nursing is increasing: fewer people are available for this care. Because of this the elderly sometimes live independently at home without proper (medical) care. Under this circumstance, accidental falls at home are a common cause of severe injury in the elderly population. An accidental fall is an accident in which a person accidentally falls, trips or slips. Falling when using transport (bicycle, moped or scooter) are not included here, these are transport accidents. [7]

Fall accidents in the elderly population often have serious consequences. In 2018, 108,000 people aged 65 and over visited a hospital emergency after a fall accident. In other words, 3,320 hospital emergency visits per 100,000 over-65s. More than two-thirds of the injuries treated in a hospital emergency were serious injuries. 57% (57,900) had a fracture, including 14,400 elderly people who broke their hip. These fall accidents entailed € 837 million in direct medical costs for patients treated in an hospital emergency or hospitalized. This amounts to € 8,200 per accident. The vast majority of the total costs were caused by fall accidents of independently living over-75s (85%, € 749 million). [8]

In addition to serious injuries, falling of the elderly can also lead directly or indirectly to death. 1,887 men and 2,741 women died from an accidental fall in 2018, most of whom were over-80s. 25 percent of the men and 43 percent of the women who died from a fall were ninety years or older. [7]

1.3 Objective and research questions

From a technical perspective fall detection and fall prevention are two strategies to tackle the issue of falls of the elderly. A technical fall detection system can be defined as an assistive device whose main objective is to alert when a fall event has occurred. Rapid and accurate detection of a fall is a key factor in alleviating the main negative physical health consequences. Elderly with for example a broken hip sometimes lie on a cold floor for hours and in exceptional cases even longer, before there is help. The delay between the fall and the intervention has been found to be correlated with morbidity and mortality rates. [9]

A technical fall prevention system can be defined as the variety of tools and actions to help preventing accidental falls by older people. Fall prevention methods can be physical training with or without the use of training tools. A difficulty in developing this training and training tools is the fact that the accident scenario of private fall accidents is unknown in most cases. [8]

In addition to the physical consequences, falling can also have psychological consequences: many elderly who have experienced a fall are insecure or anxious, which can be the cause for a new fall. The fear for a new fall can also introduce inactivity which leads to physical decline which can also lead to an increased risk of a new fall. [10] So, at first sight it seems more fruitful to develop systems and methods for fall prevention compared to the development of fall detection systems, because preventing a fall is always better than acting “when the suffering has already been done”. However, this reasoning may not be valid because all falls cannot be prevented and many factors play a role in a fall accident, such as decline in physical health will increase the risk of falling.

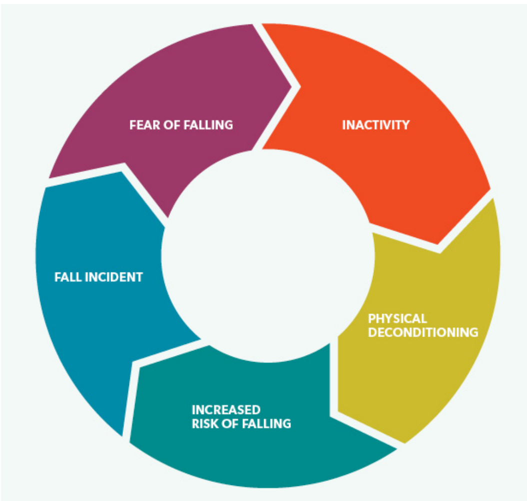


Figure 1: The Cycle of Falling [11]

In order to minimize decline in physical health due to falling, it is important to investigate where "splitting" the cycle of falling (figure 1) will have the most positive effect. It is important to respect the needs and wishes, and the abilities of the people in the target group where the risk of falling is high. In order to make a choice for a fall detection or fall prevention system, the background research will investigate how detection and prevention strengthen the conditions to let elderly people stay vital longer in their specific situation and to postpone and minimize their vulnerability. Depending on the degree of vitality, deterioration can be prevented, postponed or reduced; or can only be used to limit the negative consequences of a fall. [6]

In conclusion, the aim of this bachelor thesis is the development of a technology, that can help to decline the effects of falling in the target group being older adults, persons from 70 years old and above, addressed in this paper as elderly. This results in the following research question and sub research question:

> *Main research question: How can a decline in physical health due to falling of elderly be reduced by means of fall-related technologies?*
>
> *Sub research question: What technical fall detection and prevention methods can be used to achieve this goal?*

1.4 Report outline

To provide an answer and a solution that meets the demands of the elderly (and caretakers) in this thesis first existing fall-related technologies will be examined, described and compared (chapter 3). On the basis of this state-of-art research and taking into account the current regulations and restrictions concerning COVID-19 (chapter 2), a conclusion will be drawn whether the research will continue with fall detection or fall prevention. Hereafter stakeholder identification and analysis through interviews and surveys will be conducted. A preliminary list of requirements will be drawn on the basis of the results of the interviews and surveys (chapter 4). Finally, description of the development steps of a prototype that will be built and tested will be described (chapter 5 - 8). The overall structure of the document is derived from the Creative Technology Design Process which will be explained in 'Methods and Techniques' (chapter 3).

In order to provide a fall related system which meets the needs and expectations of the elderly, user involvement will be applied to the different stages of the development of the system. This aspect (validation of the product) is important because it will be a technical solution. Most elderly have a distance to modern technology, so there is a risk that it is too technical for them and they may reject to use it.

CH 2_Impact of COVID-19

2.1 Current situation

In December 2019, an outbreak of a new disease (COVID-19) caused by the coronavirus was reported in Wuhan, China. Most patients have a fever and respiratory symptoms. Older people, and those with underlying medical problems like cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness. Measures are being taken in the Netherlands and worldwide to prevent the further spread of the novel coronavirus. [12] The measures that have been issued by the Dutch national government to control the coronavirus situation, effect the University of Twente heavily with immediate effect.

2.2 Rules and regulations

The COVID-19 situation (social distancing, working remotely, minimizing face-to-face interactions, UT labs and buildings closed, etc.) has caused implications for Creative Technology Graduation Project 2019-2. The guidelines and regulations that apply to this graduation project are:

1. *Face-to-face contact must be avoided.*
2. *Do not approach people in the care sector.*
3. *Live testing constraints with tangible prototypes: not allowed to test with others than housemate's community or family.*
4. *Equipment, tools and resources: UT labs and buildings are at least closed till the end of the academic year for Creative Technology students..*

2.3 Consequences

The measures that have been issued by the Dutch national government and the guidelines and regulations that apply to this graduation project will have an impact on the approach and content of the project. As a result, no research can be conducted in professional health care institutions, for example care homes. Communication with the main target group of elderly people will be difficult because they generally don’t use modern forms of communication like skype. All stakeholder input will also have to be obtained digitally. In addition, face-to-face testing of a physical prototype will also not be possible. Throughout the project, the best ways of dealing with the situation in a creative way will be chosen to make the project a success.

CH 3_Background research

In this chapter, background information will be given on the context and involved concepts of a fall among the elderly. After this, relevant literature for both fall detection and fall prevention will be discussed and an overview of the current state-of-the-art will be given. The purpose of this is to learn what type of systems are currently in use, to learn about the different aspects of a fall, and to understand fall-related technologies. Finally, both fall-related methods will be evaluated and compared to ultimately achieve a starting point for further research.

3.1 Background information

The following questions will be addressed in this section of the chapter:

1. *What are the main causes and risk factors for the elderly to fall?*
2. *Which places in and around the house are the most likely for a fall?*
3. *What is fear of falling and what are the main causes of fear of falling?*
4. *What influences elderly users' acceptance and adoption of smart-home technology for ageing in place?*

Answers to these questions contribute to general understanding of falls among older populations, and thereby will contribute to develop a fall-related technology that reduces the decline in physical health.

3.1.1 Reasons causing falls

To develop a fall-related device, first it is important to be aware of the difference between activities of daily life (ADL) (walking, standing, sitting, lying) and falling, and moreover which intrinsic and extrinsic factors cause a fall. Discrimination between a fall and an ADL is not an easy task since certain ADL's, like lying on a floor or sitting on a floor from a standing position generate strong similarities to falls. [13] However there are multiple features to differentiate between fall cases and ADL. These features include falling speed, stride time, acceleration coordinates, posture information, inactivity periods, angular velocity, increasing of heart rate, change in breathing. [14] There are several reasons why such a fall happens. Some reasons cannot be controlled, whereas other causes can be controlled or modified (figure 2). The presence of more than one cause of falling is common, and several studies have shown that the risk of falling increases dramatically as the number of causes increases. The factors associated with falls/causes of falls can be classified as extrinsic/environmental (e.g. loose carpets, wet or slippery floors, poorly constructed steps) and intrinsic/personal (e.g. age-associated physiological and neurological functions changes, medications, as well as disease) (figure 2). Differentiating between these extrinsic and intrinsic circumstances increases the understanding of falls among older populations, and thereby allow to develop more specific measures for the prevention of such falls and the development of detection equipment. [15]

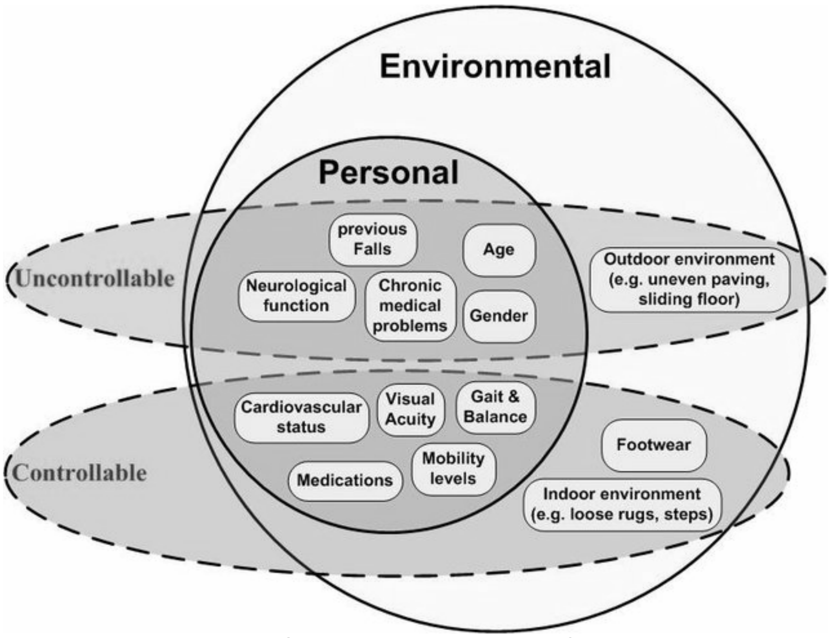


Figure 2: Common reasons causing falls [15]

3.1.2 Location of fall

In [16] Kelsey et al. it is stated that most published studies of risk factors and interventions combine all falls regardless of location. Failure to separate indoor and outdoor falls can make it difficult to assess the magnitudes of associations of various risk factors with falls; in fact, associations may be completely missed when all falls are combined, since indoor falls tend to occur to frail people who suffer from compromised health, but outdoor falls occur most often to active people. In the research of Kelsey et al. [16] among 765 cohort members living in Boston with median age at baseline 78 years, it was discovered that of the 1122 falls for which location was reported, 598 (53.3%) occurred indoors and 524 (46.7%) outdoors. Article [17] supports the discovery that most of the falls of the elderly occur indoors (67.9%). [17] states that among 500 elderly living in China, 190 (38.0%) reported falling at home in the past 12 months. These subjects (those that fell) had an average age of 79.5 ± 7.4 years and consisted of 68 (35.8%) men and 122 (64.2%) women.

In the Netherlands, falls of elderly people with minor injuries (no hospitalization) are often not reported. This complicates research into the precise location of a fall. Report [8], [8] gives information about private fall accidents of the elderly aged 65 who have been hospitalized as a result. Almost half of the fall accidents occurred in and around the private home (47%). The majority of fall accidents inside the house occur in sanitary areas, bedrooms and living rooms. In most cases (41.66%) the scenario is unknown. One in five elderly people aged 70 years and older were treated in an emergency department after a fall accident because they stumbled in and around the home.

3.1.3 Fear of falling

It has already been mentioned in the introduction *(chapter 1)* that fear of falling is an important factor in increasing the chance of recurrences of falls. Many fearful older persons resort to activity restriction, which in the long term may adversely impact both physical and mental health and actually increase risk of future falls. [18] Approximately 25% to 55% of community-living older persons acknowledge being afraid of falling; the prevalence is even higher among women and persons with a previous fall history. [19] The results of study [18] clearly demonstrate that individuals who reported fear of falling only for home-environment activities, were older and had significantly less psychological and social resources, as well as more difficulty with physical performance. Not surprisingly, they also demonstrated lower global functional capabilities. From the patient's perspective, immobility may be considered as a psychological response to previous falls or a self-protective behavior to prevent a next possible fall. However, from the medical perspective, fear of falling is a vicious cycle that can physically and psychologically restrict patient activity and mobility, owing to the physical imbalance, lack of self-confidence, low self-efficacy, and low self-reliance. [20] The effect of fall-detecting devices on the fear of falling is likely to be substantially affected by user perception of the reliability and accuracy of the detector. Difficulties in wearing the device and the level of false alerts, both false positive and false negative are a cause for concern. [21] It has been suggested that fear of falling should be treated by improving physical skills and fall-related efficacy to counteract excessive fear and avoidance behaviors during activity performance. [19]

3.1.4 Acceptance of elderly people towards smart home technologies

Technology offers a challenge and an opportunity in providing support and in enhancing the daily lives of older people. For fall related technologies to be successful, it is crucial that the potential users have a positive attitude towards these technologies and are ready to embrace these solutions in their daily lives. However, older adults explicitly reserve the right to decide for themselves what they allow into their own homes, and questions have been raised on the readiness of community-dwelling older adults to accept and use these technologies. [22] Acceptance of technologies that are electronic or digital may be more difficult for the current generation of seniors which did not grow up with these types of technologies. In an effort to understand older adults' usage and non-usage of modern technology, researchers often turn to a technology acceptance model (TAM). [23]

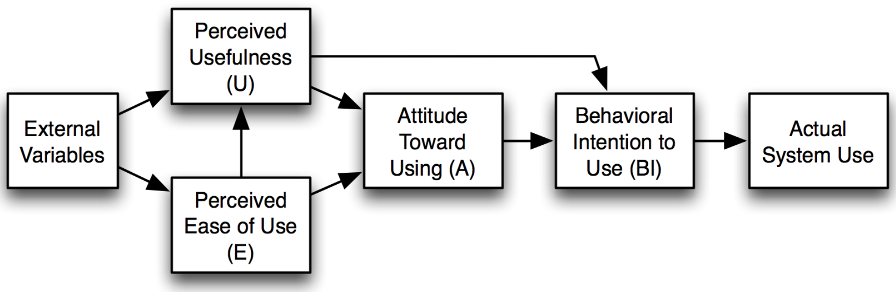


Figure 3: Technology acceptance model (TAM)

Community-dwelling older adults express various concerns when they consider technology for aging in place that they have not yet used. Their major concerns are: privacy implications, usability, no control over the activation and deactivation of the technology, fail to achieve its goal and it may prove to be ineffective. [22] In a related concern, participants are worried that other people may perceive them to be in poor health or frail, once they are seen wearing technology that is specific to frail older adults. This fear of stigmatization can be very powerful, and one participant described wearing a personal alarm button as like wearing a “badge of dishonor”. [24] Whether or not community-dwelling older adults are willing to use technology also depends on their perceived personal need for technology. Perceived need is the most frequently mentioned factor overall, and when it is present the acceptance of technology is more likely. [22]

Validation (ascertain the product meets the needs of the user) of fall-related technologies is also an important factor for the acceptance of new technology. Research on fall-related technologies has often been carried out in a laboratory setting and not in practice. It is therefore important to take into account the needs of the target group and to involve the target group in the development and implementation of technology, so that this technology will actually be used. [25]

Another interesting finding was that the seniors’ views of technology change between the pre- and post-implementation stages. Some negative concerns that appeared in the pre-implementation stage appear as positive characteristics in the post-implementation stage. In the post-implementation stage, seniors realize the wide variety of benefits that technology can have on their lives. [22]

3.2 Fall-detection

3.2.1 Literature review on fall-detection

A fall detection system can be defined as an assistive device whose main objective is to alert when a fall event has occurred and can be divided in two main groups: the primary fall detection systems that instantaneously detect falls and the secondary fall detection systems which detect falls by the absence of normal activities. [26], [27] Depending upon the source from which the data is collected, human fall-detection systems are categorized into three broad categories, as shown in figure 4: wearable device based systems, context-aware based systems and vision based systems. [28]

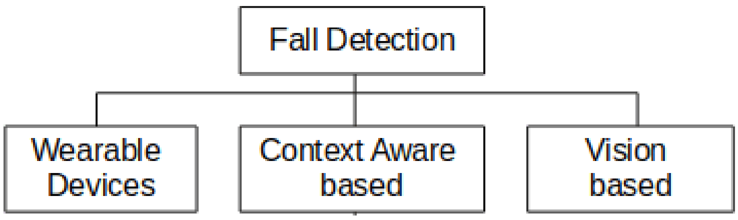


Figure 4: Classification of fall detection methods

1. In wearable device-based systems, the sensors used for fall detection are embedded within a wearable device worn by the subject, such as a wristband. The parameters monitored by such systems could include the following: heart rate variability (HRV), electrocardiogram (ECG),

pulse oximetry (SPO2), and kinematic attributes measured by accelerometers, gyroscope, and magnetometer. [29]

2. Context-aware sensing-based systems work on input from sensors placed in the environment. Some examples of such systems include ambient and acoustic sensors such as pressure sensors, floor sensors, infrared sensors, and microphones to collect data. [28]

3. Vision-based systems do not perform any parameter monitoring of the subjects; instead, they rely on image processing techniques on the video frames or images captured by cameras around the region of interest. Vision-based techniques monitors real-time movements of a person by a normal video camera or a depth video camera and in the background an algorithm is run in a dedicated PC to determine the posture of the person. [13]

In figure 5, the trend of the number of studies being conducted in wearable, ambient and camera-based sensors is shown. [30] It shows that wearable sensors have the most research interest in the last five years.

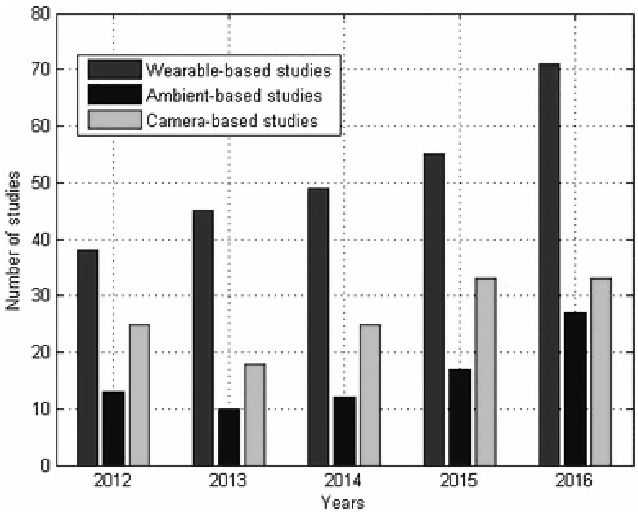


Figure 5: Trends in fall detection based on the number of studies published each year

In most cases, the performance of the detector is expressed in terms of sensitivity (SE) and specificity (SP). [26] The detector's performance strongly depends on the algorithm used. Three types of detection algorithms for detecting a fall are commonly used in all three fall detection categories: threshold based algorithms, machine-learning based algorithms and combination of threshold and machine learning algorithms. The majority of the systems employ threshold based algorithms (TBA).

1. Threshold based algorithms use a predefined fixed value to decide on a specific event. Human motion data is collected using the various sensors. The collected sensor data is then compared with some pre-set values. These pre-set values can be specific sensor values, or differences between two or more sensor readings, etc. A decision to report a fall is taken based on whether the sensor values exceed the required criteria defined in the system or not. [31] The threshold

setting in the algorithm significantly affects the performance of the system. A high threshold value results in a large amount of fall missing issues, while a low threshold value causes false alarms. Therefore, appropriate thresholds should be chosen and set.

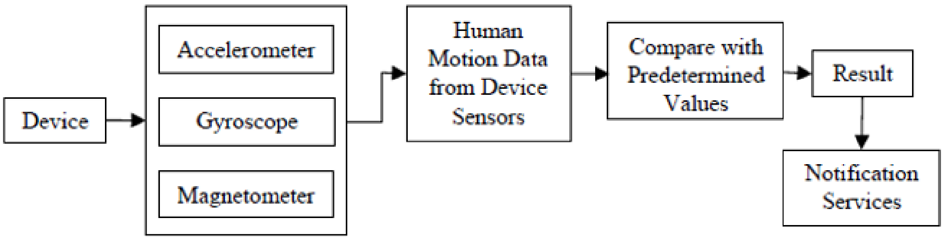


Figure 6: General block diagram of threshold based fall detection system [32]

2. Machine learning (ML) is a subfield of Artificial Intelligence (AI) where a computer can learn from sequences without the help of raw programming. Most of the systems employing machine learning algorithms require the sensors to be kept in a specific position relative to the body to operate correctly. ML based technologies produce better results compared to threshold based algorithms. Machine learning algorithm can be customized to detect different falls; and it can manage anomalies such as noise well. [31], [28]

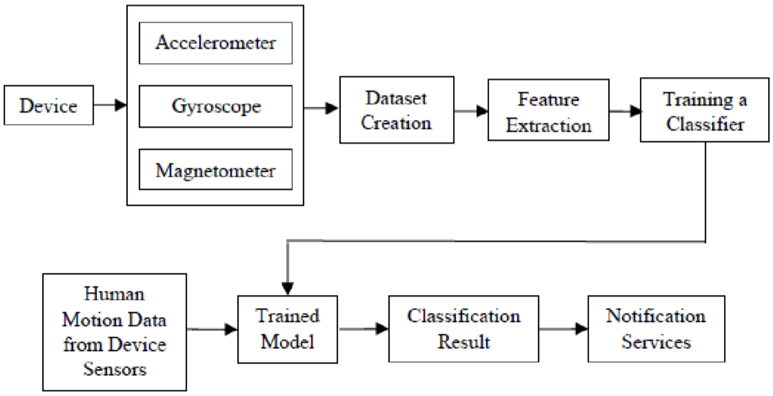


Figure 7: General block diagram of machine learning based fall detection system [32]

3. Combined fall detection systems use both pre-set sensor data and machine learning models for performing the classification task. Human motion data collected from sensors are stored and used to train a machine learning model. The combined system architecture can be arranged in many ways. The threshold based algorithm can be used for only detecting possible fall events. The possible fall events motion data is then sent to the pre-trained classifier model for final classification. [28]

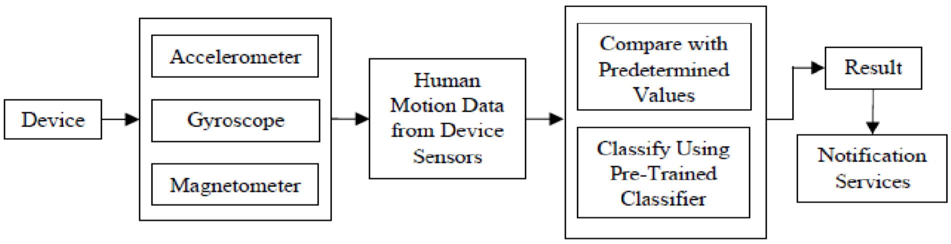


Figure 8: General block diagram of combined fall detection system [32]

3.2.2 State-of-the-art on fall-detection

Several fall detection products are currently available in the market. Most of them are wearable devices with ease-of-use designs. In this section an overview of the current state-of-the-art will be given in the area of fall-detection devices designed for elderly. The products as listed in this section are selected from a long list of found existing products. Only the not obvious products are shown to get extra creative inspiration. Because the devices differ a lot in functionality, technology and design it was decided not to compare them in a table and therefore the pros and cons are listed per device.

Apple Watch Series 4

Apple Watch is a wearable device with many functions. [33] One of these functions is fall detection. If Apple Watch detects a hard fall while wearing the watch, it taps on the wrist, sounds an alarm, and displays an alert. The user has a choice to contact emergency services or dismiss the alert. If the Apple Watch detects that the person wearing the watch it is still moving after the fall, it waits to respond to the alert and won't automatically call emergency services. If the watch detects that the person wearing it has been immobile for about a minute, it will make the call automatically including information of the location. After the call ends, the watch sends a message to the emergency contacts with the location letting them know that the watch detected a hard fall and has dialed emergency services. The watch gets the emergency contacts from the Medical ID of the owner. Apple Watch cannot detect all falls. The more physically active the user is, the more likely the watch will trigger a fall detection due to high-impact activity that can appear to be a fall. Apple Watch is less suitable for the elderly because it is small and difficult to operate by the elderly.

Figure 9: Apple Watch Series 4 [33]

Walabot HOME

Walabot HOME is a wall-mounted safety device that detects falls automatically. [34] It can automatically tell if someone has fallen by analysing the entire room space using radio frequency sensor technology. No cameras, pendants or bracelets are required. There are no wearables (necklaces, watches, etc.) and no button that needs to be pushed to indicate an emergency. In the event of a fall, the emergency contact is notified through a two-way voice call. The primary caregiver will also receive a SMS notifying them that a fall has occurred. A disadvantage of Walabot HOME is that elderly people living independently in a private home have to place a device in every room in their house.

Figure 10: a) Walabot HOME. b) Exploded view showing components of Walabot HOME [34]

Evone Smart Shoe

The Evone Smart Shoe has built in sensors to detect if the wearer has fallen over. [35] After a set time the primary caregiver will receive automatically a notification that a fall has occurred. Via a vibration in the shoe the fallen person receives the message that help is on the way. The advantage of this solution is that it can also be used everywhere outdoors. A wide range of types and styles of shoes with this device mounted is available.

This solution is less suitable for the elderly, because disadvantages of the shoe for the elderly are that they must be worn always also inside the house and they do not offer any protection during the night. The Evone Smart Shoe can be used by the elderly as a supplement to another fall detection system.

Figure 11: Exploded view of Evone Smart Shoe . [35]

Philips Lifeline service: HomeSafe with AutoAlert

HomeSafe with AutoAlert provides the benefits of a classic medical alert system, but is enhanced with AutoAlert, a highly tested fall detection technology. [36] Philips offers an additional paid service: the 'Philips Lifeline service'. At the press of the button or if the fallen person is unable to press the button, a help call will still be sent to the Philips Response Center, where trained care specialists are available, who can connect them to the support they need. When subscribed to the 'Philips Lifeline service' the caregivers can download the Cares app. The most important feature of Philips Cares app is the care circle – a network created by inviting the family and friends who actively participate in the care. The care circle can share notes and communicate about care needs, can update availability to respond etc.

all within the same digital space. Disadvantage of the system is that one has to subscribe for the paid service to get access to the full functionality of the system.

Figure 12: Philips Lifeline service: HomeSafe with AutoAlert

Hip'Safe

The HIP'SAFE airbag for seniors has two airbags to ensure a perfect protection against hip fractures. The system is integrated inside an aesthetic belt with an easy to use click system that automatically switches the power of the belt to when removed. The HIP'SAFE airbag for seniors has two airbags which are designed like a drop to ensure a perfect protection against hip fractures. [37] When the airbag is inflated, it covers a larger area than a traditional hip protector. It protects all the hip area from the top of the hips to the middle of the thighs. When a fall is detected, both airbags inflate simultaneously in a fraction of a second over the hips. The protection allows a better shock absorption and avoids hip fracture. After the impact, the airbags remain strong during some seconds and then automatically deflate slowly. A disadvantage of this system is that it is uncomfortable to wear, especially during the night when elderly get out of bed not wearing the airbag they are not secured to reduce the consequences of a fall. It can also make the older people feel uncomfortable because everyone can see they are wearing it. Advantage of the system is the prevention of adverse consequences of a fall such as a broken hip.

Figure 13: a) The system is integrated inside an aesthetic belt. b) Airbags designed like a drop [37]

Feedback-loop technology

A new technology of analyzing voltage noise could be used for fall detection. Every home emits something called voltage noise: a steady hum in the electrical wires that varies depending on what systems are drawing power. The researcher Patel stated [38] that if there were some way to disaggregate this noise, it might be possible to deliver much the same information as cameras and motion sensors. Lights going on and off, for instance, would mean that someone had moved from room to room. If a blender were left on, that might signal that someone had fallen—or had forgotten about the blender, perhaps indicating dementia. If we could hear electricity usage, Patel states, we could know what was happening inside the house. The challenge for Patel was translating the cacophony of electromagnetic interference into the symphony of signals radiated by specific appliances and devices and lights. Patel defined the algorithms that could discern a blender from a light switch from a television set and so on. All this data could be captured not by sensors in every electrical outlet throughout the house but through a single device plugged into a single outlet. This system has still to be further developed and in most cases it will not give a direct alarm after a fall, but only after a while when the movement pattern has been analyzed by the system. [38] Fall detection systems can be divided in two main groups: namely the primary fall detection systems that instantaneously detect falls and the secondary fall detection systems which detect falls by the absence of normal activities. This system is clearly in the second group now, but over time when this technology has further improved it may transfer to the first group.

3.3 Fall-prevention

3.3.1 Literature review on fall-prevention

Studies have tackled the problem of falls using fall detection approaches exhausting a variety of sensing methods. Lately, researchers have shifted their efforts to fall prevention where falls might be spotted before they even happen. The first approach utilizes fall-detection technologies to detect falls and notify others for help when a fall event occurs. However, this approach is reactive since it can only mitigate the severity of irreversible consequences. In comparison with the first approach, the second one is proactive which prevents fall occurrences through interventions. [39]

Despite this, from a technical point of view the research into fall prevention has not been researched by scientists for a very long time and less research has been done than into fall detection. Very little is known about this and the approach to fall prevention through technology is very diverse. In addition, most studies focus on non-technical interventions, such as patient-centered education, exercise-based interventions focusing on balance retraining or adaptation or modification of the home environment, improved footwear etc. [11]

Fall prevention in the broadest sense can be described as a variety of actions to help reduce the number of accidental falls suffered by older people. The most consistently proven predictors of fall risk are history of a fall during the past year and gait and balance abnormalities. [40]

Gait and balance parameter are assessed using either semi-subjective or objective assessment tools. The first are usually conducted by clinicians and often use functional performance traditional scales (Performance-Oriented balance and Mobility Assessment (POMA)) to evaluate gait and balance. Results are scored in a semi-subjective way. In contrast, objective assessment tools with advanced sensor technologies provide a large amount of reliable information on patients' gait and balance. These tools are deployed in a gait laboratory with specific technical skills to run them. However, these tools are performed in clinical settings. Given the fact that elderly prefer to stay in their own home comfort (low adherence of conventional physical therapy); efforts must be put to export gait and balance assessment into homes. [39]

Exergames can provide a solution for this. Exercise games (exergames) are becoming increasingly popular among elderly people. Many Exergames that are to be used among elderly users should be specifically designed for this group of people. [41] Recent developments in the field of sensor technology unlock great opportunities for using exergames as balance training tools. Exergame devices are controlled using a broad variety of sensor systems and, depending on the source of input, different algorithms are needed for game control and feedback. The most widely used sensors in exergame input devices include accelerometers, gyroscopes, infrared (IR) and RGB optical sensors/cameras and pressure sensors . [42]

Exergames have several advantages compared to conventional exercises: (1) Exergames can motivate people to practice through an attractive and interactive way and train both motor and cognitive skills when users performing dual tasks; (2) The players can focus their attention on the outcome of the movements in the game, not on the movements itself; (3) The exergame can be undertaken at home, either alone or remote within a small group, which may make the activity more accessible to many older adults. [42]

Although the number of controlled studies examining exergames remains small, the studies report an increase in balance ability using clinical and instrumented outcome measures after the training period. Especially elderly tend to be more homebound, and many are both suffering from loneliness and a lack of physical activity. The exergames can be used to motivate and persuade seniors to exercise more and more together with other elderly simply because it is fun. Games with remote controls and motion sensors that require the players to move, have become very popular. Many of these games are also being played by the senior population. [42]

3.3.2 State-of-the-art on fall-prevention

The state-of-the-art on fall prevention technology focuses mainly on two methods: development of systems for electric walking aid with fall prevention and variants using technology for exercising of gait and balance. Many features used in industrial robots can also be used in these systems. The development is very multidisciplinary and difficult because experts in electronics, mechanical engineering, control algorithms, and biomechanics need to work in close harmony. In addition, researchers have previously focused on the low-hanging fruit of helping users walk steadily, without worrying about preventing falls.

Active Pelvis Orthosis (APO)

Some researchers are trying to take preventive action for falling with powered exoskeleton, braces for the legs with motorized joints that assist while walking. But the braces are usually bulky and slow, and most people don't need their assistance with every step. So the researchers set out to solve that problem with a device that would take action only when needed. The new Active Pelvis Orthosis (APO) consists of a waist brace holding motors on the hips that move lightweight carbon-fiber links connected to thigh braces. [43] It uses an algorithm that monitors leg movement; if the legs diverge from a natural gait in a way that suggests a slip, the motors apply force to help the legs counteract the slippage. After the start of a slip, the APO reacted within a third of a second, correcting a person's gait for a quarter of a second. Stick figure analysis showed that—without the help of an additional restraining harness to prevent real falls—they would have fallen without help from the APO.
The disadvantage of this system is that it is uncomfortable to wear. Especially during the night when elderly get out of bed not wearing the APO they are not secured to prevent a fall. It can also make the older people feel uncomfortable because everyone can see they are wearing it and they can feel disabled. It can be difficult for the older person to put on the device alone without assistance.

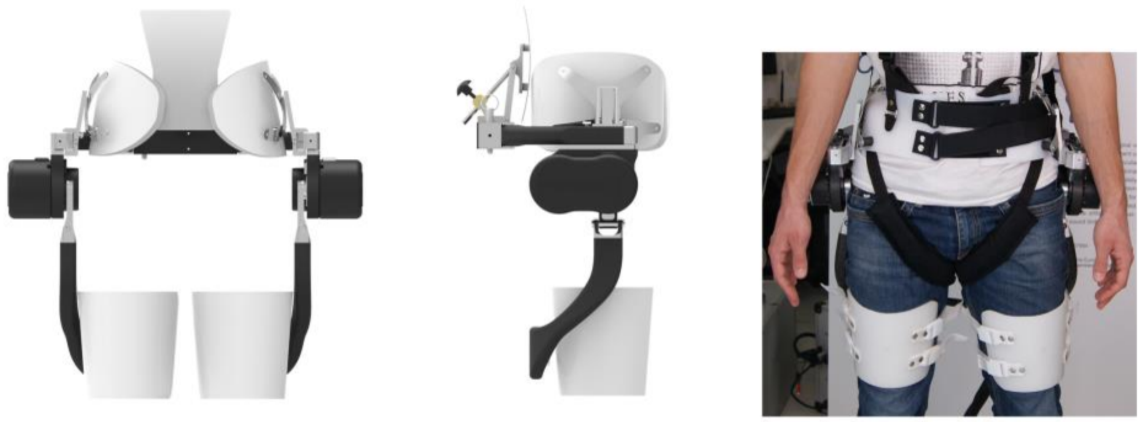


Figure 14: Robotic Walking Aid (front view, side view, worn by person) [43]

Cane-type walking-aid

An ongoing development is the cane-type walking-aid robot system as shown in image 11. [44] This robot consists of an omni-directional platform, an industrial personal computer (IPC), a six-axis force sensor under the handle and two laser sensors. The force sensor is used for detecting the interaction force from the user to estimate the user's motion intention. The deficiency of the cane robot is that it can be overturned easily because of its small size and lightweight. Therefore, a controllable universal joint is designed for adjusting the tilted angle of its stick. The stability of the cane robot during the fall prevention procedure can then be enhanced by controlling the tilted angle of stick to an optimal position. A center of pressure (COP)-based (COP-FD) method is used to detect the risk of falling. In this method, the user's COP is calculated in real time using an integrated force sensory system, which comprises a six-axis force/torque sensor and an in-shoe load sensor. When the COP reaches the boundary of the specified safety area, it is assessed that the user is going to fall down. The COP-FD method can be used in various cases of falling. However, for cases of stumbling, a rapid fall detection method is proposed based on leg motion detection, and Dubois' fuzzy possibility theory is applied to adapt to different users. The disadvantage is that all four legs of the cane must be in contact with the floor at all times during gait to provide stability which hinders fast gait. It is also not suitable for stair climbing.

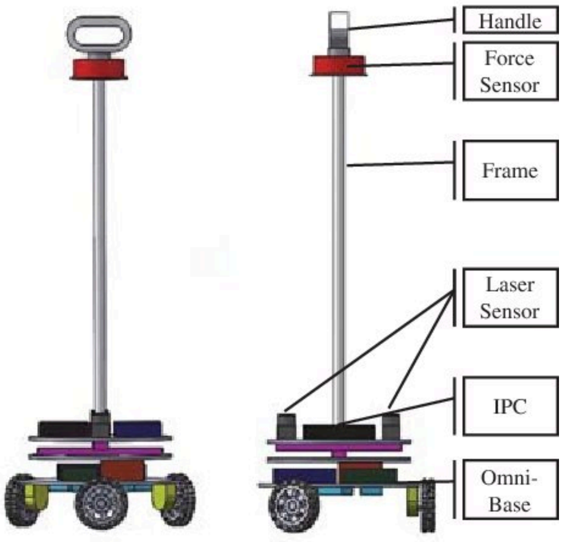


Figure 15: Cane-type walking-aid robot system with annotations [44]

Wii Fit + Balance Board

Wii Fit motivates people to exercise daily with over forty different activities in four categories: Aerobics Exercises, Yoga, Balance Exercises and Muscle Training. [45] Results and progress of all users are tracked in the Wii Fit channel, which is always available in the Wii menu after download. The Nintendo Wii includes a Wii fit balance board and the Wii sports games with handheld "Wii motes". A shift of center of pressure (CoP) is an indirect measure of postural sway and thus a measure of a person's ability to maintain balance. Though originally designed as a video game controller, the Balance Board has become a tool for assessing CoP which has proven to be both valid and reliable. Clark et al. performed a study to prove the validity and test-retest reliability of the use of a Balance Board.

Figure 16: a) The Wii Fit Balance Board b) Persons interacting with Wii Fit Balance Board [45]

Biodex Balance System SD

The Biodex Balance System is a high-end product meant for hospitals, universities and physiotherapists. [46] The training exercises of the Balance System SD are geared to improve strength, range of motion, gait and balance for those patients suffering from neurological involvement associated with Parkinson's, Stroke or Peripheral Neuropathy. In practice, the Balance System can capture, quantify and document a patient's relative tendency to overcompensate to one side or the other. Biodex Balance Assessment for Concussion Management is used by high school, college, and professional sports teams to unravel the mystery of concussion and to bring together best practices. Extremely versatile, it is the only system that provides a fast, accurate Fall Risk Screening and Conditioning Program for older adults; closed-chain, weight-bearing assessment and training for lower extremity patients, and adds the objective balance assessment component to a concussion management program. The Balance System SD also serves as a valuable training device to enhance kinesthetic abilities that may provide some degree of compensation for impaired proprioceptive reflex mechanisms following injury.

Figure 17: The Biodex Balance System SD [46]

3.4 Evaluation and conclusions

The aim of this chapter was to gather insight into the fall-related technologies (fall-detection and fall-prevention) that are currently available by doing literature research and state-of-the-art research, to gain knowledge and creative inspiration to get to a starting point for the rest of the project: development of a fall-related technology to reduce decline in physical health.

At first, falling of the elderly was analyzed, by providing sufficient background information about: reasons for a fall, locations of a fall, the fear of falling and acceptance of elderly towards smart home technology. This research on the background information of falling in the elderly population created a clear understanding of the problem and its origin. It also emphasizes the importance of technological intervention in minimizing the consequences of these incidents.

The literature review on fall-detection systems showed that these systems can be categorized in three groups based on their sensors and usage: wearable, context aware and camera based systems. Besides the aspect that a fall detection system has to mitigate the consequences of a fall such as reducing the response time, it also must be reliability and give confidence to the user. These factors have a direct relationship to the number of false positives and false negatives generated by the device which highly depend of the used algorithm.

The literature research on the fall-related technologies also showed that significant more research has been done into fall detection than fall prevention, but that science is gradually shifting from fall detection to fall prevention technology. Fall detection systems have helped reduce the consequences of falls (long lie, fear of falling); however, they did not stop them from happening. Thus, the problem of falling can be rather tackled using prevention systems/methods. Scientists generally agree that the main fall prevention method is improving balance and gait. Exergames can provide a technical solution for this.

The state-of-the-art research on fall-detection showed that several fall detection products are currently available in the market. New products are still developed using new technologies such as feedback loop technology, a new technology of analysing voltage noise. Innovative products like Apple Watch are less suitable for the elderly because the device is difficult to operate by the elderly.

The state of the art research on fall-prevention showed that several fall prevention products are currently under development and that only a few are available in the market. In regard to the fall prevention systems two types of systems can clearly be distinguished: walking aids that take preventive action for falling and exercise devices to improve gait and balance.

3.5 Study objective

The target group for this research are older adults, persons from 70 years old and above, addressed in this paper as elderly. Falls are a major health problem for frail elderly. The study objective of this bachelor project is the development of a technology that can help to decline the effects of falling in the target group. The current COVID-19 crisis, as described in chapter 2, causes many additional rules and regulations for this bachelor project. This means that the work for this GP has to be done within these principles and rules that currently apply. This has far-reaching consequences for this GP, especially given that the target group is older adults and a lot of input was needed from workers in the medical sector which also makes the evaluation and validation of prototyping complicated.

The current COVID-19 crisis brings also radical changes to the lives of frail elderly. Because the elderly are extra vulnerable to corona, the RIVM and the Ministry of Health have advised the elderly to isolate themselves, even from their children or grandchildren. Many elderly can no longer go outside and therefore have very few opportunities to move and exercise outside. This leads to a huge restriction of freedom of movement, while an active lifestyle and regular exercising is very important for preventing falls and reducing the fear of falling.

Exergames can provide a solution for balance and gait exercising at home. The remote care element is very important here, because it enables a therapist or caregiver to monitor and give advice remotely. The caregiver does not have to enter the home of the elderly, which minimizes the chance of the virus spreading. Another side effect of the COVID-19 crisis is social isolation. This can partly be compensated by adding a competitive / communicative element to the exergame, so several elderly can participate in an exergame simultaneously, each in their own home while they still have social contact with each other via, for example, the TV.

Darwin's evolutionary theory states that survival of the form that will leave the most copies of itself will survive in successive generations. This theory also applies to viruses, every new virus is more resistant than its predecessor. Coronavirus COVID-19 is part of this pattern of increasingly frequent epidemics that have coincided with globalization and urbanization. As the Coronavirus COVID-19 spreads, so does the sobering reality that epidemics will become more common and they will especially affect the frail elderly. Unfortunately this may become "the new normal" and this GP project will respond to this as an innovative and creative contribution to alleviate this problem to a certain extend for the elderly who are disproportionately affected by this crisis.

In conclusion, the aim of this research is to develop a remote monitored and controlled fall-preventing exercise-device for the elderly. The process of user involvement is extremely relevant, especially in the current situation for this target group. For this reason preference is given to a "need-driven" solution over a "technology-driven" solution.

Research Question: How can the decline in physical health due to (fear of) falling of the elderly be reduced by a remote monitored and controlled fall-preventing exercise-device?

3.6 Changed study objective based on expert review

De client / external supervisor of this GP is Teneo-IoT B.V. Teneo IoT B.V. is a young and innovative company, established in 2016, focused on developing smart Internet of Things solutions. It is the mission of Teneo IoT B.V. to make 1.000 companies and/or organizations more efficient, by applying Internet of Things. More specific, Teneo develops embedded systems (hardware and firmware) of these applications in house. These applications are currently being used among various market segments, such as Smart City, Smart Industry, Smart Logistics and Smart Home.

For the market segment of Smart Home, Teneo IoT B.V. wants to offer a product which makes it possible for elderly or disabled persons to be more independent and give people a more safe feeling:

Teneo Care. The GP description which was described by client Teneo-IoT B.V is the development of a fall-related technology, as described in chapter 1.

During a presentation of the first 10 weeks of Graduation Semester 2019-2, the results from the research in chapter 1 to chapter 3 were presented to the supervisor and client Teneo IoT. The feedback session that followed after the presentation showed that the concluding study objective / research question described in section 3.5 does not fit within the vision of Teneo-IoT. Teneo-Iot is looking for a fall detection device for Teneo Care. In addition, as a result of the current COVID-19 situation (chapter 2), the evaluation and validation of a fall prevention system as described in section 3.5 would become very difficult, because the testing requires involvement of the elderly. This has led to a change in the study objective and a reformulated research question.

The following restriction from the University of Twente, which is the result of COVID-19, means that further input to the project can only be gathered by approaching the elderly directly. The rule reads: *"DO NOT (in) directly approach people working in vital functions in the care sector and also do not introduce" extra contacts "between vital care workers and this elderly person".* This rule will have impact on the further implementation of the project, because information on the elderly people and falling cannot be obtained from people working in vital functions as specialists in this area. Instead this information has to come directly from the elderly and from informal caregivers / family members. Because testing and validating of a physical prototype with the target group is not allowed, a more conceptual elaboration of the product in the realization phase will be chosen.

> *Reformulated research Question: How to develop a fall-detection system for elderly that fits within the vision of Teneo Care and by focusing on a need-driven instead of technology-driven approach?*

CH 4_Methods and Techniques

This chapter will describe the methods and techniques used for the remaining chapters using the Creative Technology Design Process. [47]

4.1 Creative Technology Design Process

The design process of Creative Technology has been explained by Mader and Eggink [47] in their book A Design Process for Creative Technology. This design process consists of four phases: Ideation, Specification, Realization and Evaluation. Each phase starts and ends with a defined set of (intermediate) results. The design method is a balanced combination of Divergence-Convergence and Spiral models of design practice and bridges between technology and user needs. A visualization of the described design process can be found in figure 18.

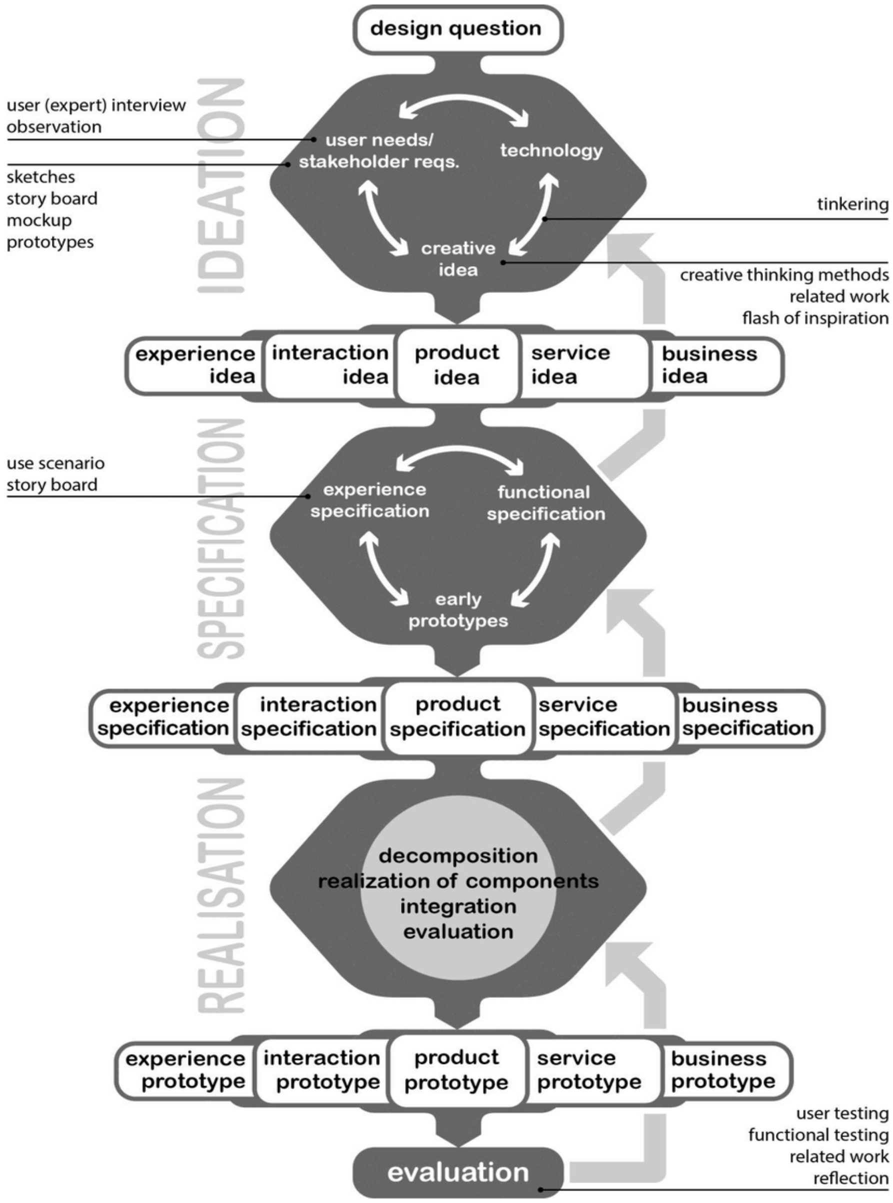


Figure 18: A Creative Technology Design Process

4.2 Ideation

The first phase of 'A design process for Creative Technology' is the ideation phase. Result of the this phase is a (more) elaborated project idea, together with the preliminary requirements. Ideas on experience, interaction, as well as a service are also part of the result. This result is achieved when a link is made between user needs / stakeholder requirements, technology and creative idea (figure 18). This can be achieved by methods such as tinkering, interviews, creative thinking, sketches, etc. The methods used in the ideation phase are described below.

4.2.1 Stakeholder Identification and Analysis

In the first phase of the Ideation, stakeholders will be identified and analyzed based on the techniques prescribed in the literature that focus on proposal development projects, given that the fall-related technology resulting from this research is ultimately a suggestion to the external GP client Teneo-IoT.
Stakeholder research is a process to find the right stakeholders from the right interest areas that will supply the input for the project. Grouping the stakeholders according to their levels of participation, interest, and influence in the project; and determining how best to involve and communicate each of these stakeholder groups throughout the project.

Bryson [48] and Sharp [49] describe stakeholders as *'any group or individual who can affect or is affected by the achievement of the organization's objectives'*. To be classified as a stakeholder, the person or group must have some interest or level of influence that can impact the project. Some of these people might have more influence than others, and also other specific requirements. Stakeholders should be involved in most aspects of the project from planning to implementation in order to achieve the goal of the project. In the article of Bryson [48] a range of stakeholder identification and analysis techniques are reviewed. The following activities have been used to identify analyze stakeholders in this project:

- *Activity 1: identification of the stakeholders*

All possible stakeholders are identified during a brainstorming session and listed in a table.

- *Activity 2: characterization of the stakeholders*

A role is assigned to all possible stakeholders. The roles are: user, decision-maker, advisor, legislator and developer. The primarily interested parties of these stakeholders are also determined. Then the stakeholders are ranked (HIGH, MEDIUM, LOW) according to their estimated project importance and influence.

- *Activity 3: mapping of the stakeholders*

Stakeholder mapping is a process of determining the key stakeholders relating to a project. For the mapping of the stakeholders it was decided to plot the stakeholders in an "onion diagram". [50] '"Onion diagram" is a way of visualizing the relationship of stakeholders to a project. Stakeholders are mapped in an onion diagram to specific layers of the project, depending on the importance for this project. A stakeholder onion diagram is usually made up of 4 or 5 layers. From the center out, these layers represent: high involvement, medium involvement, low involvement.

- *Activity 4: grid mapping of the stakeholders in importance/influence Matrix*

Making an Importance versus Influence Matrix helps to map out stakeholders and their relation to the issue at stake. It generates insights on the importance and influence of each stakeholder. The importance can be described as the priority given to satisfying the needs and interests of each stakeholder and Influence as the power a stakeholder has to facilitate or impede the achievement of an activity's objective. The extent to which the stakeholder is able to persuade or coerce others into making decisions, and following a certain course on action.

4.2.2 Interviews

In order to develop a suitable prototype, the next step after the stakeholder identification and analysis is to do additional research on these stakeholders (and target group) by means of interviews. A personal interview is a flexible means of data collection, ranging from structured, close-ended questions with predetermined response options to unstructured forms that explore new research questions. [51] The aim of the interviews is to get better insights in the interviewees' own perspectives and ideas. These interviews are used for idea generation, requirement elicitation and evaluation with the stakeholders. Three interviews will be conducted; older adult, caregiver and Teneo-IoT. These three were chosen to gain insight from three very different perspectives and maximize the diversity in insights.

The interview design and question phrasing will influence the depth and freedom with which a participant can respond. Semi-structured interviews will be used in the ideation phase of this project. With semi-structured interviewing, the open-ended nature of the question defines the topic under investigation, but also provides opportunities for the interviewer and interviewee to discuss some topics in more detail. [51] The interviews are performed conversationally with one interviewee at a time and the interviews will be conducted in Dutch. Due to the limitations of the COVID-19 situations, all interviews will take place remotely (Skype, Telephone, etc.). Before the interview takes place, an informed consent of the respondent to participate in the study will be signed (Appendix A).

4.2.3 Online questionnaire survey

In addition to semi-structured interviews, data was also collected by an online questionnaire survey, which gives a more detailed and balanced picture of the topic. This method of cross-checking data from multiple sources to search for regularities and similar patterns in the research data is called triangulation in social sciences. [52] The purpose of triangulation (figure 19) is not necessarily to cross-validate data but rather to capture different dimensions of the same phenomenon.

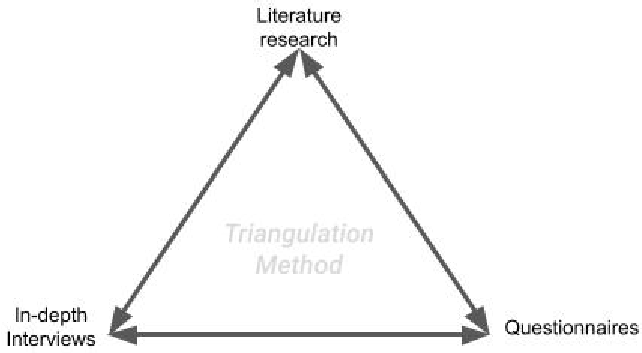


Figure 19: Triangulation method

The online questionnaire survey was designed in such a way that 3 categories of participants could complete the online survey. The corresponding questions for a specific category are automatically selected. The three categories are:

1. Caregivers ('mantelzorgers')
2. Older adults (60+)
3. Workers in the elderly care

These categories of participants were recruited via different channels; Facebook, LinkedIn, WhatsApp and the network Teneo-IoT B.V. The tool used to conduct the online questionnaire survey is Google Forms [53]. The online questionnaire survey was available in Dutch and could be completed anonymously after the participants had given their consent by signing the consent form. The online questionnaire survey consisted of 62 questions divided over the three categories and the type of questions varying; multiple choice, open-ended and rating. The questions can be found in Appendix B.

4.2.4 Preliminary Requirements

When developing a product, it is important to have a clear understanding of its requirements. preliminary requirements are the starting point for the development of the first concepts. In several iterations, the requirements will become more detailed and specific. The (preliminary) requirements are first categorized into functional and non-functional requirements, then prioritized using the MoSCoW-method and finally criticized using the SMART-method.

Functional and non-functional requirements

First, the requirements will be divided into functional and non-functional requirements. Functional requirements define the basic system behavior. Essentially, they are what the system does or must not do, and can be thought of in terms of how the system responds to inputs. Functional requirements are product features and focus on user requirements. While functional requirements define what the system does or must not do, non-functional requirements specify how the system should do it. Non-functional requirements concern the operation of the system, such as technical requirements or other non-user-facing functionality. [54]

MoSCoW Method of prioritization

Requirements prioritization is defined to be the process that specifies the importance order of the requirements. A project failure can occur if wrong requirements' priorities are chosen. In this project the MoSCoW method will be used to categorize the requirements into different priority groups. It defines four priority groups: ”MUST have”, ”SHOULD have”, ”COULD have” and ”WON’T have”. [55], [56]

- “MUST have” means that requirements in this group must be contained in the project. Failure to deliver these requirements means the entire project would be a failure.
- “SHOULD have” means that the project would be nice if it contains the requirements in this group.
- “COULD have” also means that the project would be nice if it contains these requirements. But these requirements are less important than the requirements in the “SHOULD have” group.
- “WON’T have” is like a “wish list”. It means that the requirements in this group are good requirements but they will not be implemented in the current stage. They may be implemented in the next release.

SMART criteria

Using the SMART framework [57] every requirement can be verified as correct in terms of expression (not content). Each letter in SMART refers to a different criterion for judging objectives / requirements. The criteria are:

- “Specific” – precise and not open for interpretation.
- “Measurable” – can be qualified as complete or not and avoid undefined time-periods.
- “Attainable” – able to achieve given the existing environment.
- “Realistic” - relevant and are appropriate in context with other requirements.
- “Time-related” – specify when the result(s) can be achieved.

4.2.5 Scenarios [1]

Stakeholders having similar roles could share overlapping and complementary stories which can be combined into coherent scenarios with unambiguous context. Scenario building gives a possibility to explore and communicate the qualitative aspects of user experience early in the design process. The scenarios serve as something concrete to base discussion, argument and resolution of issues. By employing them, scenario-based design brings the focus of design closer to the activities that need to be supported, strengthens the understanding and gives rationales to the requirements. [58]

PACT

A PACT analysis [59] is a useful tool to create user centered scenarios and to give insight into the requirements of the system. The acronym PACT stands for People, Activities, Contexts, and Technologies. The PACT analysis is useful for both analysis and design activities; understanding the current situation, seeing where possible improvements can be made or envisioning future situations. The results of the PACT analysis will provide the starting point for a detailed concrete ‘scenarios of use’ in the specification phase.

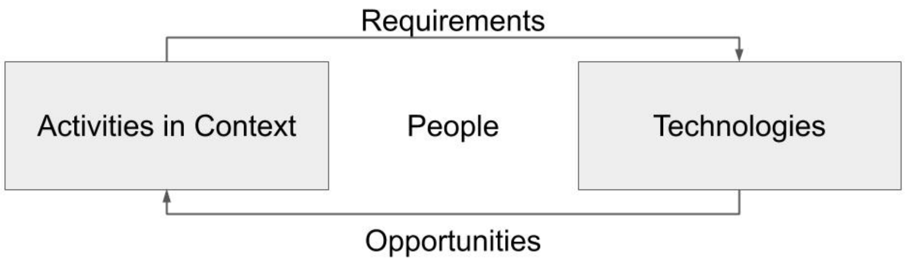


Figure 20: The PACT-analysis framework

4.2.6 Concept generation

For the generation of novel ideas on fall-related technologies for elderly, different brainstorm sessions will be conducted. First an individual brainstorm session was conducted to generate the first product ideas based on the information gained in the background research, interviews and surveys. The technique used in this brainstorming session is mind mapping. [60] A mind map is a non-linear graphical way to represent ideas and concepts. Free-form, spontaneous thinking is required when creating a mind map, and the aim of mind mapping is to find creative associations between ideas. Thus, mind maps are principally association maps. The preliminary requirements were drawn up on the basis of this first brainstorm. After this, a second brainstorming session took place in which brain-sketching technology generated different concepts for sub-parts of the product.

4.3 Specification

The final concept and the evaluated preliminary requirements of the ideation phase will be the starting point for the specification phase. According to the Creative Technology Design Process [47] it is characteristic for the specification phase that a number of prototypes are used to explore the design space, and that a short evaluation and feedback loop is applied. Since several concepts have already been developed in the ideation phase, the specification phase in this project will focus more on specifying the final concept that arose from the ideation phase. So the specification in this research is about setting goals and expectations for one iteration of a fall-detection product, namely the final concept. Several diagrams are used to display the functionality that is aimed to fulfill the requirements. Furthermore, detailed scenarios that are based on the PACT-analysis done during the ideation phase will give insight in the user journey.

4.3.1 Product architecture diagrams

Different types of diagrams have been used to explain and describe the functionality that is aimed to fulfill the requirements of the product and to explain and describe the different subparts of the total product.

Functional system architectures

Block diagrams are used to visualize the functional system architecture, the levels and relations of different parts in these levels. The functional system architecture consists of two layers to describe the system. The first level focuses on the breakdown of the product in functional blocks (black boxes) with the functional interfaces between these functional blocks. The second level describes the different functional blocks (white box) of the system.

Functional flowchart

Functional flowcharts [61] have been used to describe specific internal system functions. The flowchart shows the steps as boxes of various kinds, and their order by arrows connecting the boxes. The two most common types of boxes in a flowchart are:

- a processing step, usually called activity, and denoted as a rectangular box.
- a decision, usually denoted as a diamond.

Wireframe user flow

To describe the app on a structural level, a wireframe user flow was used. A wireframe [62] is commonly used to layout content and functionality. Wireframes are used early in the development process to establish the basic structure of a app (functionality, behavior, and priority of content) before visual design (typographic style, color, or graphics) and content is added. This technique of wireframing is combined with an application user flow. User flows are diagrams that display the complete path a user takes when using the application. The user flow lays out the user's movement through the application, mapping out each and every step the user takes—from entry point right through to the final interaction.

4.3.2 Scenarios [2]

Based on the PACT analysis as described in the ideation, a follow-up scenario has been made to describe the user interaction with the final concept.

User journey storyboard

A user journey [63] is the experiences a person has when interacting with something. User journey focusses on the user; what they see and what they do. User journeys intends to show the big picture but for a single user category. Its narrative line focuses on the chronology of phases and actions that a single user has to perform in order to achieve his or her objectives. In this thesis, this narrative line will be used in the form of a storyboard.

4.4 Realization

After the product specification is finalized, the next phase will be the realization phase. In this phase the first step is to explore the needed components for the final product concept and prototypes of the wearable device and the smartphone app will be realized. These prototypes are based on the then most actual list of requirements as well as the architectures of the specification phase. Which frameworks are used for creating this prototype and how they are used for the realization will be explained. The prototypes will be tested and reviewed in the evaluation phase.

4.5 Evaluation

In the last phase of the Creative Technology design process, evaluation on the final concept will be performed. After the evaluation has been completed in a satisfactory way, the Creative Technology Design Process is completed.

4.1.5 Evaluation set-up

Participants

The evaluation of the concept will be carried out with various stakeholders. In this way, feedback will be obtained from both experts and end users. The evaluations will be conducted with:

- Owners of Teneo-IoT B.V. , 2 participants (expert review)
- Employees Teneo-IoT B.V. , 6 participants (expert review)
- Informal caregivers, 2 participants (end user review)

A different evaluation procedure will be drawn up for each group of participants. The evaluation with the informal caregivers, for example, focuses more on user-friendliness and the evaluation with the expert, for example, also on technical feasibility of the product concept.

Procedure

Due to the restrictions of the current COVID-19 situation, the evaluations are conducted online. Two different methods are used: evaluation sessions and online questionnaire evaluation. Part of both evaluations will be a usability test of the smartphone app.

- *Evaluation session*

The online oral evaluation sessions will consist of expert reviews with the owners of Teneo-IoT B.V. and end user reviews with informal caregivers. The evaluation sessions will be "one-to-one sessions" and will be held via Skype and recorded so feedback can be easily analyzed and evaluated afterwards. The structure of the evaluation session is semi-structured. This means that the topics are set-up beforehand, but the session is held conversation-wise, so there will be enough space for questions, feedback and recommendations of the participants.

The usability test consists of two parts: first task-based and thereafter unguided usability testing. During the task-based testing, participants are asked to perform specific tasks within the app. The actions of the participant can be monitored and analyzed by means of screen sharing. During the unguided usability testing, participants are asked to explore the app for 5 minutes. The thinking out loud method is applied in which the participant expresses all his thoughts.

- *Online questionnaire evaluation*

The online questionnaire evaluation will be done by the employees of Teneo-IoT. For the questionnaire evaluation, the online questionnaire tool Google forms will be used. In the questionnaire both open and closed questions are asked. The open questions are aimed to invite participants to give longer responses that demonstrate their reasoning and explanation. The closed questions are a mix of multiple-choice questions and rating scale questions.

The usability test in the questionnaire evaluation consists of the same two parts: first task-based- and thereafter unguided usability testing. During the task-based testing, participants are asked to perform specific tasks within the app. After each task, the participants are asked to fill in, for example, within how many clicks they have been able to perform the action and to describe the purpose of a particular action. During the unguided usability testing, participants are asked to explore the app for 5 minutes. After the 5 minutes, participants are asked to provide general feedback and recommendations and then to complete a set of rating-scale questions.

Structure

Table 1 shows the structure and components of the evaluations. The fully detailed evaluations can be found in Appendix I and Appendix J.

Table 1: structure for both evaluation sessions and online questionnaire

Nr.	***Sections***
1	Explanation of the evaluation
2	Consent and privacy policy
3	Introduction
4	Demographic questions
5	Questions about wearable device
6	Usability test smartphone app
7	Questions about smartphone app
8	Questions total product
9	Debriefing questions
10	Concluding the evaluation

Topics

In order to assess whether the final product meets the needs and wishes of the stakeholders, various topics were discussed during the evaluations. The usability test measures the subjective usability of a product or service based on usefulness, satisfaction and ease of use. [64] Besides that, the user

experience and user interface (UX / UI) are evaluated. Figure 21 shows UX and UI topics that have been taken into account in the evaluation. UX evaluation is important to get answers to questions like: 'Does the user perceive the functions in the system as useful and fit for the purpose?' and 'Does the user feel that it is easy and efficient to get things done with the system?'
Finally, the evaluation also included questions about the assessment of technical feasibility, estimated costs and selling price and related ethical issues.

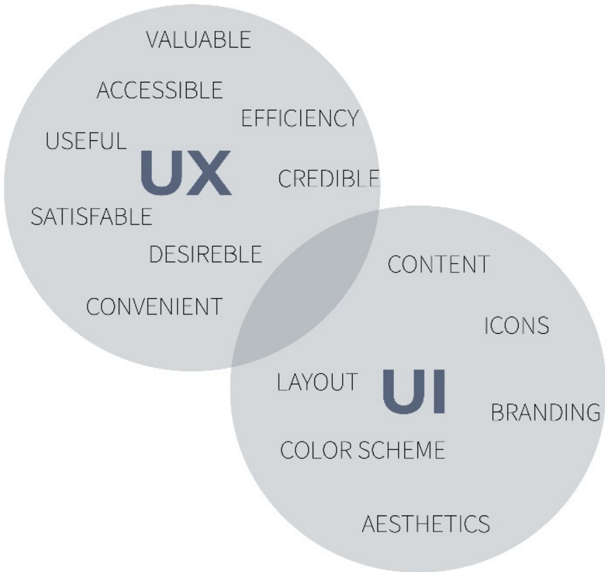


Figure 21: UI / UX evaluation topics

CH 5_Ideation

In this chapter the ideation phase of this project is described. The starting point for this ideation phase is the concluding research question from chapter 3. With this research question in mind, the aim of this chapter will be to gain insight into the stakeholders, to generate a variety of ideas, conceptualize these and find an idea for further development. Gaining insight into the stakeholders will be done by interviews and surveys. The preliminary requirements will be drawn up on the basis of the findings of these interviews and surveys. Next a PACT analysis is presented that explains the principles for a subsequent scenario in the specification phase.

5.1 Stakeholder identification and analysis

The stakeholders in this graduation project are limited to the parties involved in [development, implementation and utilization of the project. The stakeholders in this graduation project are identified and categorized on their roles, primarily interest, estimated project interest and influence (table 2). Figure 22 visualizes the involvement of the stakeholders in this project, in such a way that the identification of the stakeholders is clear at a glance. Figure 23 shows the interest / influence matrix based on theory of Brynson [48].

Table 2: List of stakeholders with assigned role, primarily project interest and estimated project interest/influence.

Stakeholder	***Role***	***Primarily interest***	***Estimated project interest***	***Estimated project influence***
Older adults (70+)	User	Reduce decline in physical health due to (fear of) falling.	HIGH	HIGH
Teneo-IoT	Decision maker	Contribute to a product that they can place in the market segment of Teneo Care.	HIGH	HIGH
Caregiver (‘mantelzorger’)	Secondary user	An aid to reduce decline in physical health due to (fear of) falling for the elderly.	HIGH	HIGH
Community nurse / caretaker	Secondary user / advisor	More efficiency will require less direct care.	MEDIUM	MEDIUM
Family members	Advisor	Less emotional worries.	MEDIUM	LOW
Medical Policy Advisors	Legislator	The end product must comply with the applicable policy.	LOW	LOW
Network providers	Advisor / resources	Use their computer interface/network for the product.	LOW	LOW
Municipalities	Legislator	Cost savings, because it contributes to the policy to allow older people to live independently at home for longer.	LOW	LOW
University of Twente	Legislator	Guidelines for the graduation project, which are now extra important due to the corona restrictions.	LOW	HIGH

Supervisor GP project	Decision maker	Ensure that the project is scientifically approved and guidance.	LOW	HIGH
Health professionals	Advisor	Use of the system in professional health care institutions.	MEDIUM	LOW
Physiotherapists	Advisor / (secondary users)	Use of logged and monitored data to improve the physical health of the elderly.	MEDIUM	MEDIUM

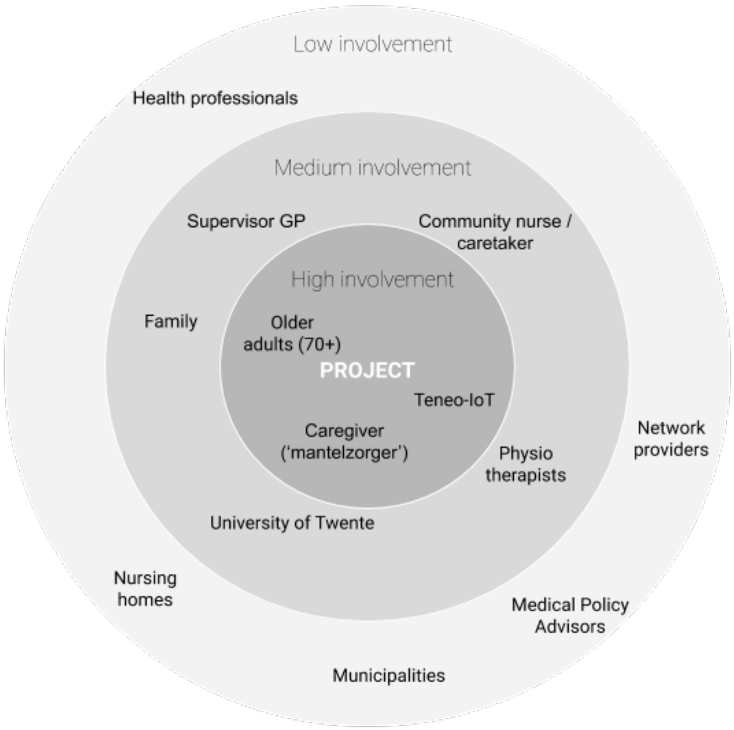


Figure 22: Union diagram involvement in project

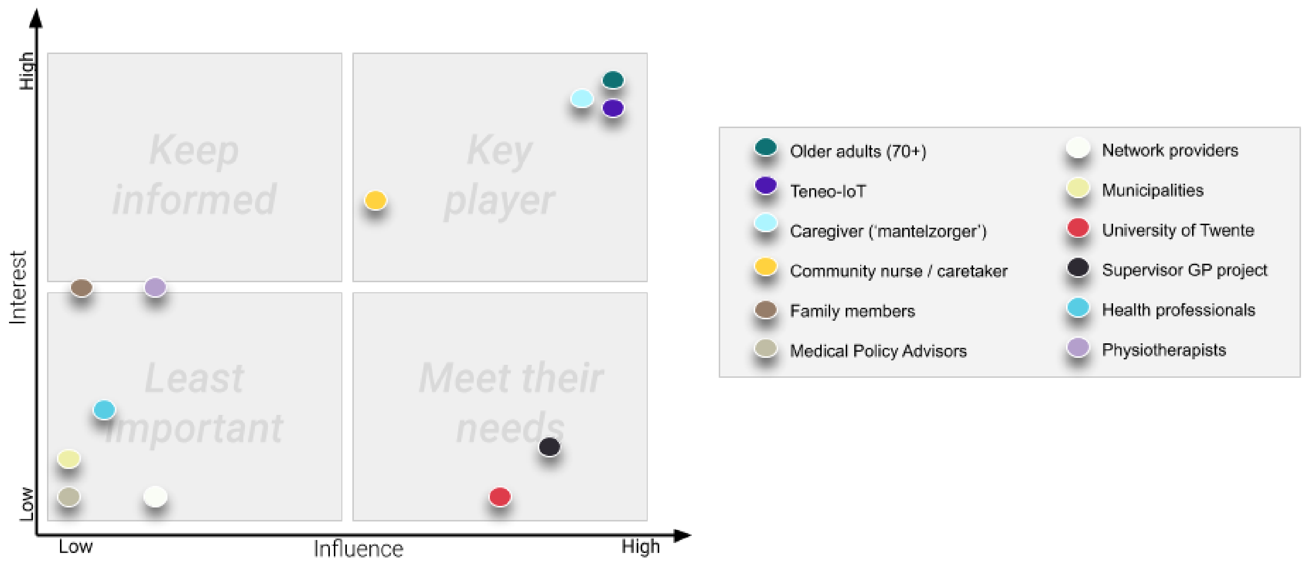


Figure 23: Interest / influence matrix

The interest / influence matrix shows (figure 23) that older adults have a high interest and high influence. As end-users of the system they will provide the key requirements as input for this project. The system has to satisfy the needs of the older adults, such as a short response after a fall, help to prevent from falling and reducing the fear of falling. Teneo-IoT is also a party with high interest and high influence, because the end product has to fit seamlessly in their development path of a fall detection system (Teneo Care). Teneo-IoT will also provide key requirements such as market price and used technical interfacing network. From the perspective of the caregiver the system has to be reliable and give the right information on the location. The experience of working with older adults of the caregiver will contribute to the requirements for usability of the product. The community nurse/caretaker has a medium interest and a medium influence. The main interest of the community nurse/caretaker are the improved efficiency, because the direct attendance can be reduced thus give them more time for other tasks. The interest of family members is to feel comfortable, knowing that somebody is notified in case the loved one is fallen. But their influence is low. Especially in this time with the COVID-19 crisis the influence of the University of Twente is high. The additional restrictions and regulations due to the Covid-19 crisis have a high impact on this project. The supervisor GP project has a high impact on the project, because he has to ensure that the GP complies to the scientific standard of a bachelor GP.

5.2 Outcomes interviews

Several qualitative interviews were held with the stakeholders in addition to the survey to gather further information and in order to get insight into their specific requirements for the envisioned product. The interviews were all semi-structured and also functioned as brainstorming sessions. The question protocol of the interview can be found in Appendix A. The interview questions were divided into several topics. Below the most important insights per stakeholder are listed.

5.2.1 Teneo-IoT

The interview was conducted with the external supervisor Mrs. I. Heideman of Teneo-IoT, the client of this project. The main aim of this interview was to gain more insight into the unique selling points of Teneo-IoT to be able to draw up specific resulting requirements.

- The first interview question related to the general mission and vision of Teneo-IoT specifically for ‘Teneo Care’.
    - IoT: Making one thousand organizations future-proof by 2030 by offering smart solutions (Internet of Things - IoT solutions) and thereby offering greater efficiency and efficacy in processes to make these processes more sustainable.
    - Teneo Care: creating a sustainable living environment for the elderly (and informal caregivers) by giving the elderly the opportunity to be more independent and give people (elderly and informal caregivers) a more safe feeling. Nowadays many informal care tasks end up with family. Teneo Care can help reduce some of the burden on informal caregivers by sharing the responsibility for frail older people with more people.
- Furthermore, during the interview was asked about the ‘unique selling point’ for Teneo Care. The most important unique selling point are listed below:

    - Combine data from different sensors to minimize the chance of false-positives / false-negatives and thereby optimizing functioning of the system.
    - Simple and straightforward.
    - User-friendly for the target group of elderly people.
    - The system is not linked to the professional emergency services. This means that help can be on site faster and at a lower price than, for example, the traditional emergency button, because no "subscription costs" have to be paid for Teneo Care. Moreover, this makes Teneo Care deployable nationwide.
    - The use of LoRaWAN® as a network. LoRaWAN® is very suitable for sensor networks, because it has a low power consumption. The downside of this is the low bandwidth. In the field of privacy, LoRaWAN® is very suitable, because the messages are fully encrypted.
    - It includes GPS functionality so the location of the fallen older person can be traced directly. Using GPS functionality new options like geo-fencing and route guidance can be implemented.
    - Linking a wearable to an associated app. This link could be made by scanning a code / tag on the device by the app. This app should be usable by the informal caregivers and other relatives of the user of the device. The app could also store data for research purposes, at the explicit consent of the user of the device.
    - Waterproof and robust because the device has no plug connections to the outside.
- The interviewee said that Teneo-IoT has no preference in the type of wearable. Most important are, the wearable is comfortable to wear and the wearable functional. To allow the detection system to be worn at night, the device should be made independent of clothing.
- Offering additional services (everything that is not inside the device) is less relevant for Teneo-IoT. Teneo-IoT has no specific requirements for this.
- Another topic in the interview was putting the product on the market. Teneo-IoT wants to market the product as a health care product through a sales channels for health care products. The product will, for example, be offered at a home care store such as 'het Groene Kruis'. This is the best way to reach the target group. The appearance (look and feel) of the product will have to match to appearance of the platform on which it will be sold.
- A fair selling price for the product according to the interviewee is between € 200 and € 300.

5.2.2 Older adult (70+)

The older adult interviewed for this project had experienced a fall accident very recently so during the interview this person could share his/her own experiences.

- The interviewee stated that he/she did not use an emergency button / fall detection system or other aids to prevent a fall, such as a walker. As a result, this person initially had no opportunity to call in help after the fall. Because of this experience he/she said to have a lot of interest in the fall detection system. The most important aspects of the fall detection system for the interviewee are:

    - In addition to detecting a fall, also detecting inactivity after a fall.
    - Integrate a function into the product to provide information for the alarmed person on how to enter the user's home. Possibilities mentioned: connect the app with a key box; in the app you can see who is in possession of a key; a central place where the key can be collected.
    - Personalize the alarm: Which caregiver will be notified?; In what order the caregivers will be notified?; Notification automatically after a fall or after interaction with the device?; etc.
- The elderly person interviewed also mentioned that he/she thinks it is important that the wearable is comfortable to wear. As an example, the older person mentioned that when choosing a wristband as wearable on the inside, soft material and a soft band can be used to prevent irritation of the often fragile skin. When choosing a necklace, it must be ensured that the device is not too heavy, so the cord does not gash the person's neck.

5.2.3 Informal caregiver

In addition to experience as a caregiver, the interviewee also had experience as a worker in a nursing home and at 'Buurtzorg' in the past. As a result, the interviewee had a lot of experience with the 'traditional' emergency button (figure24), which is now often used by elderly people in the Netherlands for alarming after a fall incident.

- Most of the elderly people the interviewee has taken (is taking) care of use an alarm button (estimated 7/10 elderly people) and use increases dramatically with age.
- The use of an alarm button relieves an insecure and unsafe feeling of many elderly people and caregivers. Wearing the emergency button the elderly. The use of an alarm button helps the elderly to feel calm.
- The elderly cared for by the interviewee often forgot to wear the emergency button. Often the elderly also were afraid the device would fail if they were to wear it in the shower, while the device with the emergency button is waterproof. The elderly also forget that the emergency button does not work outdoors.
- Disadvantages of the emergency button mentioned by the interviewee:
    - Emergency button only works indoors.
    - Emergency button is linked to a emergency center of, for example, 'de wijkverpleging'. This entails high "subscription costs" for the older people. Also due to this extra intermediate step via the emergency center, help is often (too) late at the location.
    - After an emergency situation, communication with the above-mentioned emergency center often takes place via an intercom located somewhere in the elderly person's home. If this person is no longer able to go to the close vicinity of intercom, communication becomes difficult and valuable time is lost.
    - The emergency button does not in any way indicate that the system is still functioning (eg battery full, intercom working). Therefore, care personnel must test the system once a month by pressing the emergency button.

  - device (watch or necklace) is stigmatizing due to the large red button.
  - The elderly complained that the emergency button is not pleasant as a necklace, because the emergency button is relatively heavy and therefore the cord gashes the person's neck
- The interviewee indicated that many elderly people who use an emergency button make little use of the possibilities of a smartphone (only for calling or a simple WhatsApp message). He/she therefore recommended that a possible app that is linked to the fall detection device should only be used by the care staff. The interaction between elderly patients and technological devices can be stiff, so the design solution should not incorporate much interaction with the older adult.
- The interviewee was very interested in a built-in GPS function in the fall detection device. However, she said that directions / guidance seemed unnecessary to her.

Figure 24: traditional personal emergency button for older adults

5.3 Outcomes online questionnaire survey

This section discusses the results of the online questionnaire survey. Methods and Techniques (4.1.1.3) describes that the online questionnaire survey could be completed by three different target groups, namely the elderly (65+), informal caretakers and professionals in elderly care. It was ultimately decided not to include the latter category in the online questionnaire survey. This is because during the COVID-19 crisis major ethical objections rest on approaching this target group for a graduation project.

To make the survey more attractive, images have been added to the invitation, the header and the consent statement (Appendix B). Nevertheless, there were only few responses, a total of 15 (9 older adults and 6 informal caregivers). The reasons for this are: the short period of time (7 days) that the survey could be completed and that the target group of older adults (65+) is often not digitally skilled enough to complete an online survey and they are difficult to contact online, for example via Facebook or LinkedIn. Because of the Covid-19, the elderly could also not be helped in completing the survey. Because of this only a qualitative analysis of the results is possible.

5.3.1 Results

The main and most striking results of the survey are listed below.

Informal caregivers

All informal caregivers said they were to some extent concerned about a possible fall accident of the person they take care of. The reasons mentioned were: has been fallen before, reduced physical health, easily distracted and careless, injuries from falls. On the statement "When the person I take care of uses new technology, he/she must be supported by care professionals." 40% responded to agree with a score rated 5 out of 6 and 60% to agree with the statement with a score rated 6 out of 6.

Older adults (65+)

3 out of 9 respondents have fallen in the past 2 years. None of these 9 respondents currently use a product or service to reduce the chance of falling or to limit the consequences of a fall. All 9 respondents within this target group have a smartphone and only 1 respondent answered that he/she does not use different apps on a daily basis.

Both informal caregivers and older adults (65+)

When asked 'Which of the options for wearing a fall detection system (for the elderly) do you like the most?', 'wristband' was most frequently mentioned (61.5%), followed by 'invisible wearing' (30.8%). When asked 'Who do you think should be alerted first after a fall?' the response was very divided (see figure 25). In the survey, a respondent advised to personalize this. Various statements about what they consider important aspects of a fall detection system have also been presented to both target groups. All of the statements could be answered on a scale from 1 to 6; 1 = totally disagree and 6 = totally agree. The average values per statement can be seen in table 3.

Table 3: Average of rating scale (1 - 6) per statement, blue = high score, grey = low score.

Statement	*Average rating*
The fall detection device must know where the user of the fall detection device is located.	5,2
The fall detection device may send an alarm after a fall without explicit permission of the user.	5,1
The fall detection device may collect motion data and remember how often, where and when the user has fallen.	4,7
The fall detection device must also be usable when the user is in bed.	5,6
The fall detection device must be voice controlled.	4,5
The fall detection device must be suitable for use in the shower (water resistant).	5,6
The fall detection device must be fashionable.	3,6
The fall detection device must be linked to a smartphone app for additional services (GPS, remaining battery life, caregiver / family chat function, etc.)	4,5

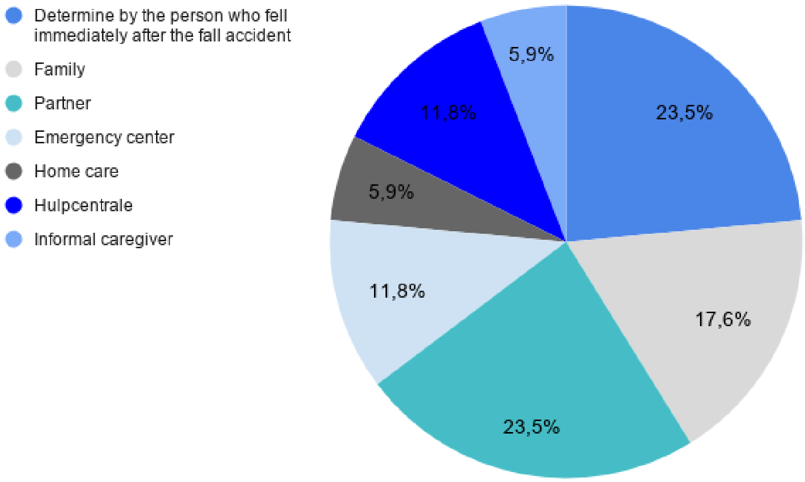


Figure 25: Results survey question about who should be alerted first after a fall incident.

5.4 Brainstorming

An individual brainstorming session has been conducted. The technique used during this brainstorming session was mind mapping. Based on previous research, it turned out that the product should consist of two parts, namely: a wearable device and a corresponding smartphone app (figure 26). This formed the core of the mind map from which creative ideas and solutions were devised for various sub-parts (figure 26) of the product. During the brainstorming, all ideas that came up and are possibly implementable are included in the mind map. The ideas put forward by participants in interviews and surveys were also included in the mind map. The brainstorming session led, for example, to new ideas for services in the app, but also to new aspects that are important to improve the requirements. The results of this brainstorming session were therefore used to prepare the preliminary requirements. The full mind map is in Appendix C.

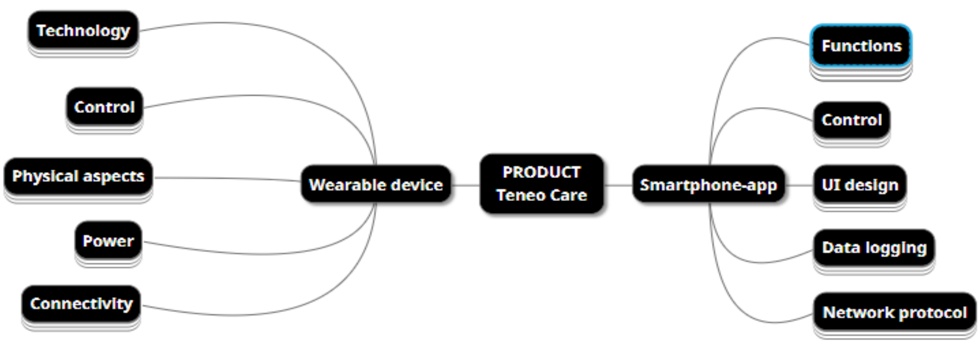


Figure 26: Subsections of brainstorm mind map.

5.5 Preliminary requirements

Table 4 lists the preliminary requirements for the product. These requirements are a result of the analysis of interviews and online survey questionnaire (section 5.2 and section 5.3) and the brainstorm session (section 5.4). The requirements are categorized conform the MoSCoW method (section 4.2.4) in MUST, SHOULD, WOULD and DON'T indicated in table 4 as respectively M,S,C and W. For each category the requirements are categorized in functional- and non-functional requirements. The decomposition and mapping of the requirements to the parts to be developed is indicated in table 4 as:

P *Product (combination of Smartphone app, Wearable device and Charger)*
A *Smartphone app*
W *Wearable device*
C *Charger*

This set of preliminary requirements will be evaluated and corrected at a later phase (see section 6.3) of the graduation project. During this requirements evaluation, the SMART framework will be used determine to what extent the preliminary requirements are unclear, incomplete (bold between brackets), indefinite or contradictory.

Table 4: Preliminary requirements

MUST			
Functional requirements	**P**	M1	The product MUST consist of a wearable device with a wireless charger and corresponding smartphone-app.
	W	*M1.1*	*The wearable device MUST be a* ***[TYPE WEARABLE DEVICE]****.*
	P	M2	The wearable device MUST have two-way communication with the corresponding smartphone-app.
	W	M3	It MUST be clear to (a hearing and/ or visually impaired) user of the wearable device that the system has detected a (possible) fall / emergency.
	W	*M3.1*	*The wearable device MUST have light actuator.*
	W	*M3.2*	*The wearable device MUST have sound actuator.*
	W	*M3.3*	*The wearable device MUST have vibration actuator.*
	W	M4	If after detecting a (possible) fall / emergency the user has not interacted with the wearable device within a ***[CERTAIN TIME]***, an alarm MUST automatically be sent to the corresponding smartphone app.
	P	M5	The product MUST have a provision to detect heart rate abnormalities.
	W	*M5.1*	*If no heart rate or heart rate abnormalities are detected by the wearable device, within a* ***[CERTAIN TIME]****, an emergency alarm MUST be issued.*
	A	*M5.2*	*If no heart rate or heart rate abnormalities are detected by the wearable device, a push notification MUST be send to the smartphone app users who have a resuscitation competence and/or access to an AED.*

	W	M6	The user MUST be able to use the wearable device without having complicated interaction.
	W	*M6.1*	*The user MUST be able to control the wearable device by **[TYPE OF CONTROL]**.*
	P	M7	The status-information of the wearable device MUST be visible.
	P	*M7.1*	*Low battery indication MUST be visible on the wearable device and* on *the smartphone app .*
	P	M7.2	*Low battery indication MUST be true when the operating time is less than **[CERTAIN TIME]**.*
	A	*M7.3*	*The availability of the wearable device MUST be visible in the smartphone-app.*
	A	*M7.4*	*A defect of the wearable device MUST be visible in the smartphone-app.*
	A	*M7.5*	*Disruption of the the connectivity of the wearable device MUST be visible in the smartphone-app.*
	A	M8	The smartphone-app MUST include a list of carers who are alerted automatically in case of an emergency on a call-by-call basis in the sequence of the predefined list.
	A	*M8.1*	*If there is no response within **[CERTAIN TIME]** of the smartphone-app user who is alerted in an emergency, the next person in the predefined list will be alarmed.*
	P	M9	In case of an alarm the product MUST show the location of the user of wearable device.
	W	*M9.1*	*The wearable device MUST be able to send location positioning information to the smartphone-app.*
	A	M9.2	*The smartphone-app MUST be able to display location position data of the wearable device after an alarm.*
Non-functional requirements	**W**	M10	One or more sensors MUST be implemented in the wearable device to detect a fall.
	W	*M10.1*	*The wearable device MUST be able to measure orientation and angular velocity.*
	W	*M10.2*	*The wearable device MUST be able to measure multi-axis acceleration.*
	W	*M10.3*	*The wearable device MUST be able to measure atmospheric air pressure.*
	W	M11	One or more sensors MUST be implemented in the wearable device to measure human body parameters.
	W	*M11.1*	*The wearable device MUST be able to measure heart rate.*
	W	*M11.2*	*The wearable device MUST be able to measure body temperature.*

	W	M12	The wearable device MUST be usable by older adults with a visual and / or hearing impairment and / or deteriorated physical health (parkinson, artrosis, heart diseases) / mental health (forgetfulness, dementia) .
	W	*M12.1*	*The wearable device MUST be controllable by older adults with a visual and / or hearing impairment and / or deteriorated physical / mental health.*
	W	*M12.2*	*The wearable device MUST be put on/put off without the help of others.*
	W	*M12.3*	*Unintended activation of control functions MUST be prevented.*
	W	M13	The wearable device MUST be wireless rechargeable.
	C	*M13.1*	*The wireless charger MUST have a battery status indicator.*
	W	*M13.2*	*The wearable device MUST be recharged within* ***[CERTAIN TIME]****.*
	w	*M13.3*	*The battery of the wearable device MUST guarantee an operation time of* ***[CERTAIN TIME]****.*
	P	M14	Network LoRaWAN MUST be used for connectivity.
	P	M15	BlueTooth MUST be used for software loading, software updates and product settings.
	P	M16	Data - and privacy protection MUST be implemented.
	W	M17	The wearable device MUST be able to send location positioning data.
	W	M18	The wearable device MUST be water resistant.
	P	M19	It MUST be possible to use the wearable device also as an emergency alarm, even if there has not been a fall accident.
	W	*M19.1*	*The wearable device MUST have a manual alarm control.*
SHOULD			
Functional requirements	**A**	S1	The smartphone-app users SHOULD be able to change their availability for help by themselves.
	W	S2	The wearable device SHOULD include the option to lock the attachment mechanism.
	A	S3	The smartphone-app SHOULD have special functions for the administrator.
	A	*S3.1*	*The administrator SHOULD be able to add and delete smartphone-app users.*
	p	*S3.2*	*The administrator SHOULD be able to pair the new wearable device to the smartphone-app.*

	A	*S3.3*	*The administrator SHOULD be able to change the priority list.*
Non-functional requirements	**A**	S4	The cognitive effort of the smartphone-app user SHOULD be minimized by simplifying data into an easy understandable intuitive representation of the GUI.
	A	*S4.1*	*The smartphone-app SHOULD use visual language, such as icons, where possible.*
	A	*S4.2*	*Every action SHOULD be activated within 3 clicks.*
	A	*S4.3*	*There SHOULD be consistency (color, font, etc.) in GUI.*
	A	*S4.4*	*The design of the GUI SHOULD be minimalist (only essential information will be showed).*
	P	S5	The product SHOULD be able to be used nationwide.
	P	*S5.1*	*The product SHOULD not be dependent on a local emergency care call centre.*
	W	*S6*	The wearing comfort / ergonomics of the wearable SHOULD be tailored to the target group.
	W	*S6.1*	*The surface texture SHOULD be soft and non-irritating where skin contact and polished where no skin contact.*
	W	*S6.2*	*The weight SHOULD not exceed* ***[CERTAIN WEIGHT]****.*
	W	*S6.3*	*The wearable device SHOULD be adjustable without assistance.*
	W	*S6.4*	*The size SHOULD not exceed* ***[CERTAIN DIMENSIONS]****.*
	P	*S7*	The selling price of the product including wearable device, wireless charger and ***[NUMBER OF ACCOUNTS]*** smartphone-app SHOULD not exceed ***[CERTAIN AMOUNT]***.
	P	*S8*	The look and feel / aesthetics of the product SHOULD reflect how it is put into the market, namely via healthcare-related platforms / shops.
	P	*S9*	The product SHOULD not be stigmatizing.
		S10	The smartphone app SHOULD provide information on how to enter the house of the user of the wearable device.
COULD			
Functional requirements	**P**	*C1*	The product COULD be voice controlled.
	P	*C2*	The product COULD be able to make an automatic emergency call (112).
	A	*C3*	The carers COULD be able to communicate with each other via live chat function in the smartphone-app.
	A	*C4*	The smartphone-app COULD include a secured medical profile of wearable device user for health professionals (ambulance personnel and doctors).
	A	*C5*	The smartphone-app COULD have integrated geo-fencing functionality which can only be set by the administrator.

	P	C6	The product COULD be able to store monitored data.
	P	*C6.1*	*Data logging COULD be used for product improvements.*
	P	*C6.2*	*Data logging COULD be used for fall-prevention.*
	P	*C6.3*	*Data logging COULD be used for (medical) research.*
	P	*C7*	*The product COULD be able to send an alert if the body temperature of the person wearing the wearable device is over 38℃ for more than 3 hours (COVID-19)*
Non-functional requirements	**P**	C8	The product COULD be sustainable.
	W	*C8.1*	*Materials COULD be recyclable.*
	W	*C8.2*	*The cord / strap / clip COULD be replaceable.*
	W	*C8.3*	*The battery COULD be replaceable.*
WON'T			
Functional requirements	**P**	W1	The product WON'T provide language settings.
Non-functional requirements	**A**	W2	De smartphone-app WON'T be used in professional care institutions.
	W	W3	The product WON'T give the user the possibility to switch the wearable device off.
	P	W4	The product WON'T give direct instructional feedback on how to improve gait and balance.
	P	W5	The product WON'T have multiple wearable devices linked to one smartphone-app.

5.6 Scenarios [1] PACT analysis

In the following section a PACT-analysis will be presented which is aimed at obtaining a clear overview of potential users, activities and possible use of technologies, as well as an understanding of the context in which the intended end product is to be implemented. It will help in developing a more detailed design brief and in writing the product scenario as can be found in section 6.2.

People

In the first chapters of this thesis, the target group of the fall-related technology was described as only older adults aged 70 years and older. Information collected during background research (Chapter 3) and the input obtained from the interviews and online survey questionnaire (sections 5.2 and 5.3) have changed the target group / end user of the project and made its description more complete.

- *Older adults*

Most users within this group are aged 70+ and are Dutch speaking. Often the users of the product are people who currently use the traditional emergency button (figure 24). The users within this group are heterogeneous, because the differences (cognitive / physical characteristics) between these elderly people who use of the product can be very different. For example, the elderly can have different physical and cognitive disabilities. Examples of different physical abilities are visually impaired, hard of hearing, general mobility problems, or an underlying condition, such as Parkinson's disease, osteoarthritis and heart disease. Examples of cognitive abilities can be dementia, anxiety disorders and depression. The use of medicines can also influence physical and cognitive abilities. This variety of disabilities leads to very different motives for using the product. In some cases, a light coercion may be necessary to ensure the use of the product. In certain cases it may be necessary the user cannot take off the device by himself. For example, if the user forgets to wear the device due to forgetfulness. All users of the product will be '24/7' users, since a fall can happen at any time of the day or night. Wearing a for everyone visible device can be stigmatizing for the elderly because everyone can see that the person wearing it is in need of help. This can be a reason for elderly not to wear it. Finally, this group of users is generally unfamiliar with technological devices and software applications.

- *Carers*

In the course of the study another group of end users was added: the carers. Traditionally, an alarm from a fall detection system is sent to the emergency care call center that is connected to the care network of the older person. A requirement of stakeholder Teneo-IoT is that an alarm is sent directly to the carers and no central monitoring center is needed. This has led to this new group of end users. This group of users is also Dutch speaking, very heterogeneous and can consist of partner, family, home care organizations, local residents and other close relatives of the elderly. The group consists of both frequent users and infrequent users, depending on how close the person is involved in the care of the older adult. All those involved have good cognitive and physical abilities, because they have to take care of the older ones. Finally, this group owns a smartphone and is familiar with technological devices and software applications.

- *Teneo-IoT*

Teneo IoT can monitor information from the system and use it for further product development such as functional product improvements and quality improvement.

- *Researchers and fysiotherapists*

A fourth group of users could be researchers and a physiotherapist. This group could use the wearable's measured data for research. The measured data can be examined for product improvements, research into fall patterns or used by a physiotherapist for fall prevention or A fourth group of users could be researchers and a physiotherapist. This group could use the wearable's measurement data for research. The measurement data can be examined for product improvements, research into fall patterns or used by a physiotherapist for fall prevention or revalidation. This group of users will be disregarded for the rest of the project. This group of users will be disregarded for the rest of the project.

Activities

- *Older adults*

The wearable device will be worn by people in their everyday life. For example, the wearable device can be used during the night while sleeping and while showering. The wearable device can also be used outdoors, for example during a walk or bike ride. During these activities, the sensors will be active and be able to detect a fall. The wearable device will mainly operate autonomously without needing any user interaction. Interaction with the wearable device is only necessary for charging the battery and when a fall is detected by the system. This will limit the cognitive load for the elderly. The wearable device can contribute to a reduced fear of falling and thus provide more peace of mind to the older person, so they will undertake more activities, become more mobile and thus reduce the chance of falling (splitting the cycle or falling, see figure 1).

- *Carers*

The smartphone app will be used by people in their everyday life. Each wearable device user is linked to a group of carers by means of the accompanying smartphone app. These carers work together in the app. Within the group there is a distinction between the different carers. Each group has one admin with special rights / privileges and the rest are team members. The responsibility lies with the admin. The activities on the smartphone app for both team admin and team members will consist of for example: indicate whether the carers are currently available for help or not, note visits in the calendar in the app and each other informed via the chat box in the app. The special activities that only can be performed by the admin are: pairing, keeping the list of carers up to date, maintaining the correct order in which the carers will be alerted, setting the radius of the geo-fence, determining which services are used. All this will have to be discussed with the older person in question. By using the smartphone app the carers have less to worry about because they are kept informed at all times via the smartphone app. The carers can communicate with each other via the app. The app can also be used to be temporarily relieved of duties by transferring the alerts and care to someone else. These functions will help to unburden the carers.

Context

- *Older adults*

Two contexts are possible for the group of older adults, namely the situation in which the older adults live independently at home or the situation in which the older adults live in nursing homes / care homes. The graduation project focuses on the first context. The wearable device forms a part of the physical context of the older adults.

- *Carers*

The physical context is the place and time users are connected to the smartphone app. This can be anywhere, anytime, as long as the user has a smartphone in their environment. For this target group, there is mainly a digital context, in the form of the app. Furthermore, all people in this group are (closely) involved in the health / care of the older person in daily life and it is important that there is a good relationship of trust between the older person and the carer. The carers are volunteers and not health care professionals.

Technology

- *Wearable device*

Inputs of the wearable device are the data received by the different sensors and the user data (activating the alarm manually). The output of the wearable device consists of light/sound/vibrations and an alert to the smartphone-app. A wearable device can be networked or stand-alone. A requirement of Teneo-IoT is to develop a networked system and to use the LoRaWAN interface and protocol. The interface for the alert to the wearable device is passive it sends only a message after a fall, in case of an emergency, in case of battery low, and when the device is not worn. It will also send location data on request from the app in case geofencing is used. The wearable device is active at all times, monitoring and analyzing the input of the different sensors. Pairing of the app and the wearable device is done by reading the QR code on the wearable device with the camera in the smartphone. Software loading, parameter setting and updating is done by Teneo IoT via the LoRaWAN interface.

- *Battery charger*

A wireless charger will be used to charge the battery of the wearable device.

- *Smartphone app*

The Smartphone-application will be running on a smartphone using iOS or Android.

5.7 Concept generation

Based on the PACT analysis, concepts were generated during brain-sketching sessions to complete and improve the preliminary requirements that were unclear, incomplete or not unambiguous.

5.7.1 Type and shape [wearable device]

The first brain-sketch session was done to determine which type of wearable is most suitable and what shape this wearable should have. Figure 27 shows a concept for a ring in the top left corner, concepts for wristbands in the middle and concepts for belt clips on the right. The concept of the ring was not chosen, because the necessary components for the detection device will not fit in a ring. In the middle of figure 27 you can see a concept where the strap can be rotated from a wristband to a pendant. This iteration gave me the idea for a modular wearable concept (see figure 28).

Figure 27: Iteration on design of wearable device

The modular wearable device consists of a supporting wearing structure and separate modules that can be attached to the supporting structure (see figure 28). Examples of these separate modules could be for example a fall detection system, a fitness tracker, sleep monitoring or modules for specific disorders such as: Multiple Sclerose (MS) or diabetes. Examples of supporting constructions could be: a wrist strap, a necklace, a clip, etc. This modularity offers Teneo-IoT BV the opportunity to use this product for different market segments.

The best shape for the module turned out to be round, because the largest component (the battery) is also round. The round shape also gives a smooth line to the narrowing wristband and besides it looks most like a normal watch.

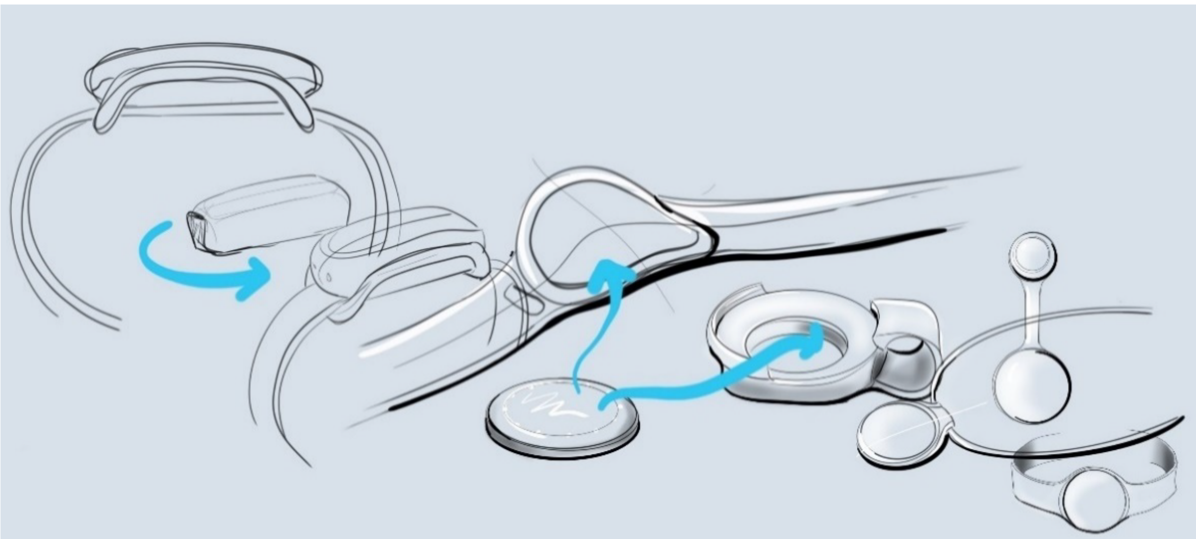


Figure 28: Modular concept for wearable device

5.7.2 Attachment mechanisms [wearable device]

In figure 29 several concepts of a suitable attachment mechanism for the wearable device are shown. The focus was the design of an attachment mechanism for a wristband. For the main user of the wearable device, an older adult (70+), it is important that the wearable device can be put on and taken off with a simple operation. In addition, it is also important that the wristband of the wearable device is adjustable in size and the attachment mechanism is not bulky. Also elderly people who do not have full control over their motor skills should be able to put on and take off the device without the help of others.

This iteration led to the idea to build a lock mechanism into the attachment mechanism (see figurex in 29 the top right corner). The wearable device can be locked by rotating the slider a quarter turn. For elderly people with dementia or who are forgetful, for example, it is important that the wearable device cannot be removed without the help of care staff. This lock mechanism allows you to choose whether the older person can take off the wearable himself or only with the help of carers. This concept is further elaborated in the specification (section 7.1.5).

The most suitable attachment mechanism with which this lock can be combined is the concept where the straps can be pushed together and one part of the wristband slides in the other part (figure 29 bottom middle). This mechanism can easily be adjusted on the wrist and locked in that position.

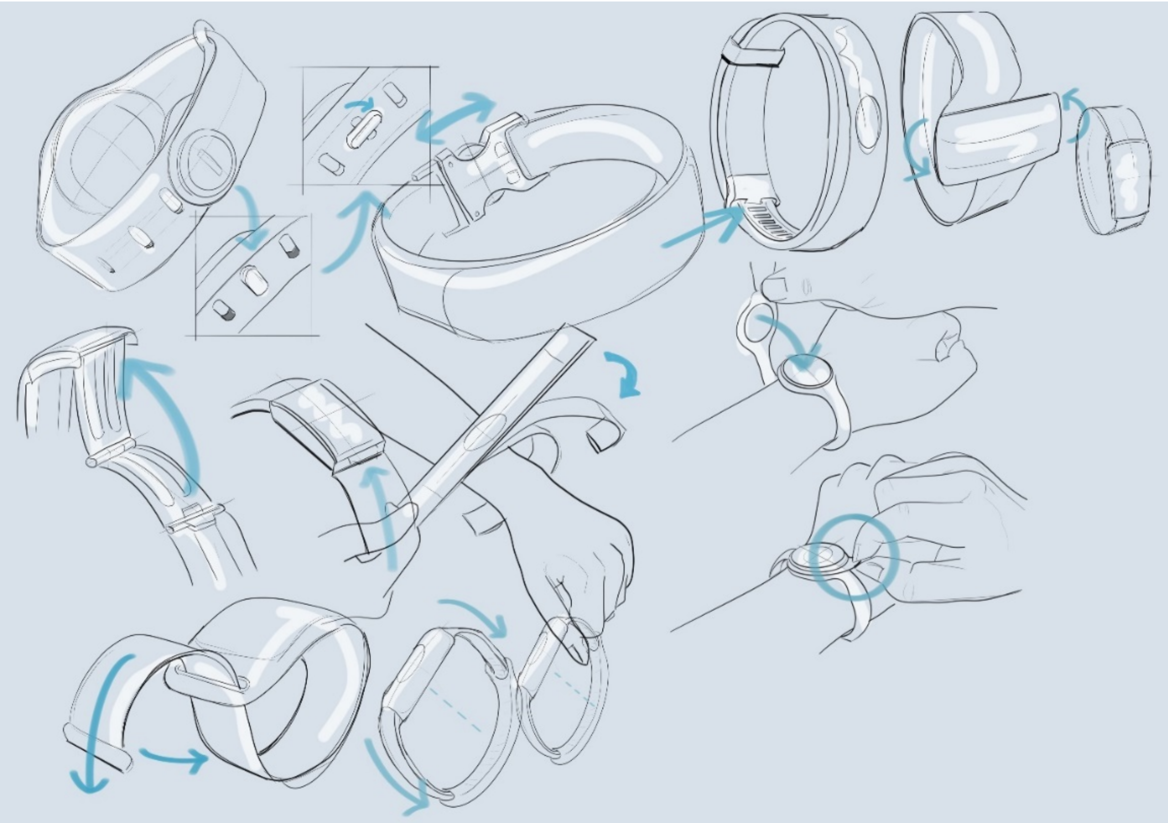


Figure 29: Attachment mechanism concepts

5.7.3 Interaction and control [wearable device]

The users of the wearable device should also be able to activate a manual alarm or cancel the alarm. For this human machine interaction to control the wearable device various options have been investigated. Different types of switches, push buttons and rotational buttons (figure 30), have been investigated. A disadvantage of a push button is it can be pressed unintentionally. This can be prevented by using a rotational button, but this is a less intuitive solution which can confuse the user in case of an emergency. Ultimately, a lowered capacitive push button in combination with the option to cancel unintentional alarms were chosen.

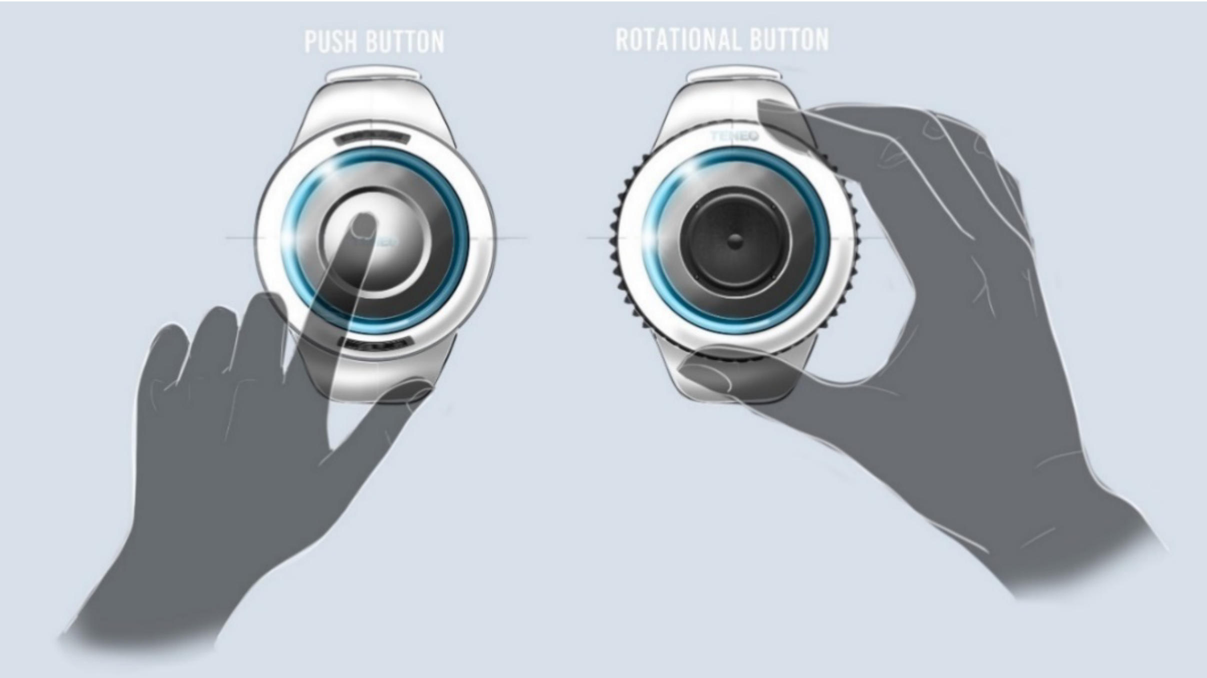


Figure 30: Interaction wearable device

5.7.4 Menu screens [smartphone app]

In addition to concept generation for various aspects of the wearable device, different options for the menu screens of the smartphone app have been explored to determine the overall layout and structure. Various ideas and concepts can be seen in figure 31.

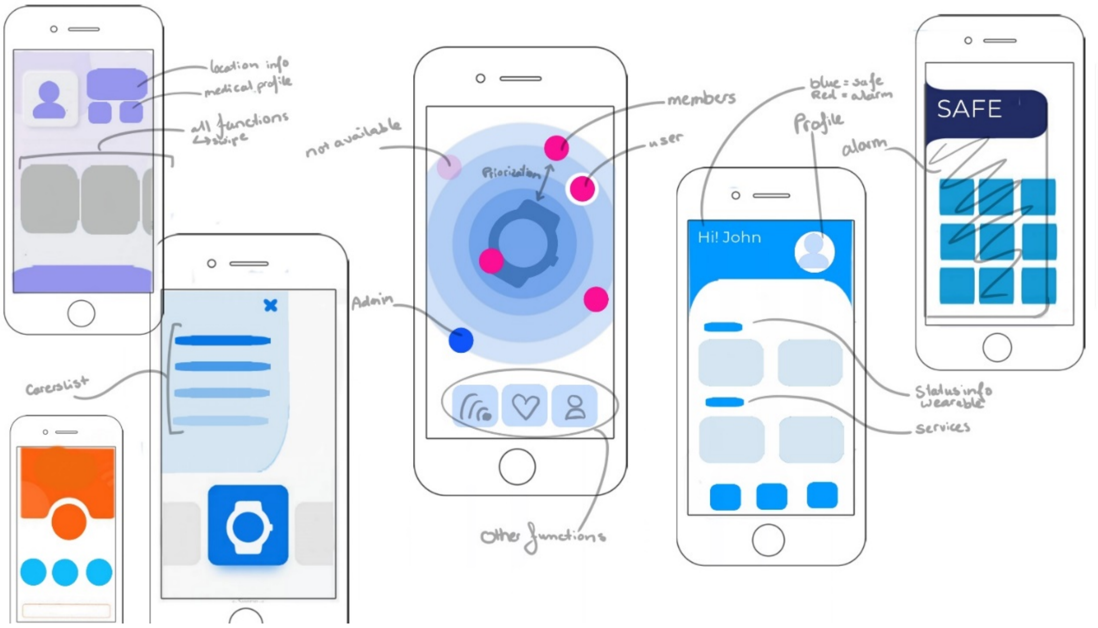


Figure 31: Menu screens smartphone app

5.8 Final concept

After exploring several concepts for different parts of the total product, a final design was created. All the insights that were gained during the background research as well as in the interviews, brainstorms and stakeholder analysis were taken into account to create a final idea. The research question requires a solution in which the needs and wishes of the key stakeholders are paramount in the development of the fall detection product. The final idea will therefore not focus on improvement of the technical aspects of fall detection, but to focus on a new innovative product in which the shortcomings of the devices that are currently in market can be improved. The main unique value / selling points and ideas for innovations of the concept are:

- The alarms go directly to the carers, and not first to a central emergency room. This saves costs and time.
- In addition to automatic fall detection, the device is able to send an alarm in other emergency situations such as heart rate abnormalities.
- The modular design enables different wearing methods (wristband, neckless, belt clip) and different applications (fall detection, fitness tracker, sleep monitoring, specific deceases like MS, Parkinson).
- The design is not stigmatizing, like traditional neckless with red panic button.
- The location of the person in need of help is available on the smartphone app.
- By applying LoRaWAN, the product can be used indoors and outdoors. But also in the shower and during the night in bed.
- A geofence can be used.

- An attachment and locking has been developed for the product, for unintended taking off by for example the elderly with dementia.
- In addition to alerting in the event of an alarm the Smartphone app has many other functions and services.
- The product is suitable for people with various conditions such as hearing impaired and visually impaired.
- The product can be extended with various additional features such as monitoring body temperature (COVID-19) and measuring oxygen saturation (COPD).

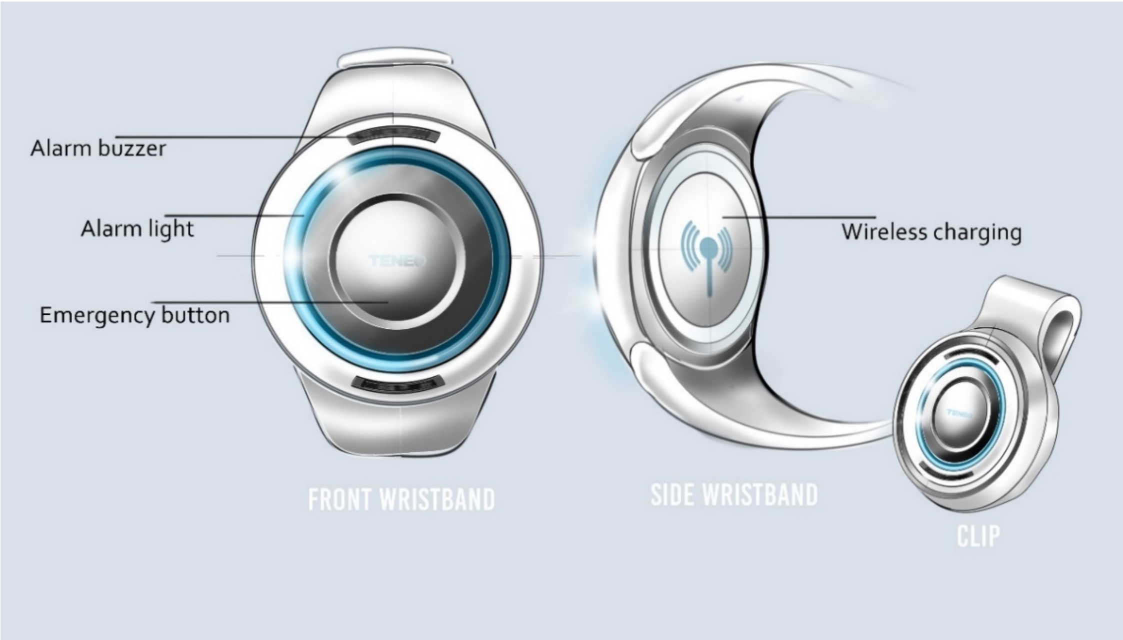


Figure 32: Final concept for part wearable device

CH 6_Specification

This chapter describes the specification phase of this project. The final concept that resulted from the ideation phase will be the starting point for a system architecture describing how the system works and should be used. The block diagrams presented in this chapter will describe the overall system, the subsystems and the interaction between the subsystems. In addition, this chapter will also provide a user case scenario.

6.1 Product architecture

This section describes the architecture of the system in several block diagrams. First a simplified overview of the system followed by a more detailed overview of the wearable device with all the physical parts and functional connections. Thereafter, the three alarming modes of the system are described in functional flow diagrams. And finally the external interfaces between the system parts are specified on the basis of a functional block diagram of the complete system.

6.1.1 System overview of product

The system consists of three physical parts, namely the wearable device, smartphone app and charger. The captured requirements have to be decomposed to these system parts and mapped on the different functional blocks in these system parts. In figure 33 the system overview with black boxes and all functional interfaces are shown. The set of system requirements are decomposed in two levels:

<u>Level 0</u> Product system

<u>Level 1</u> Product system decomposition in system parts

Wearable device

Smartphone app

Charger

The requirements are mapped to these levels see table 4 (respectively: P,W,A,C).

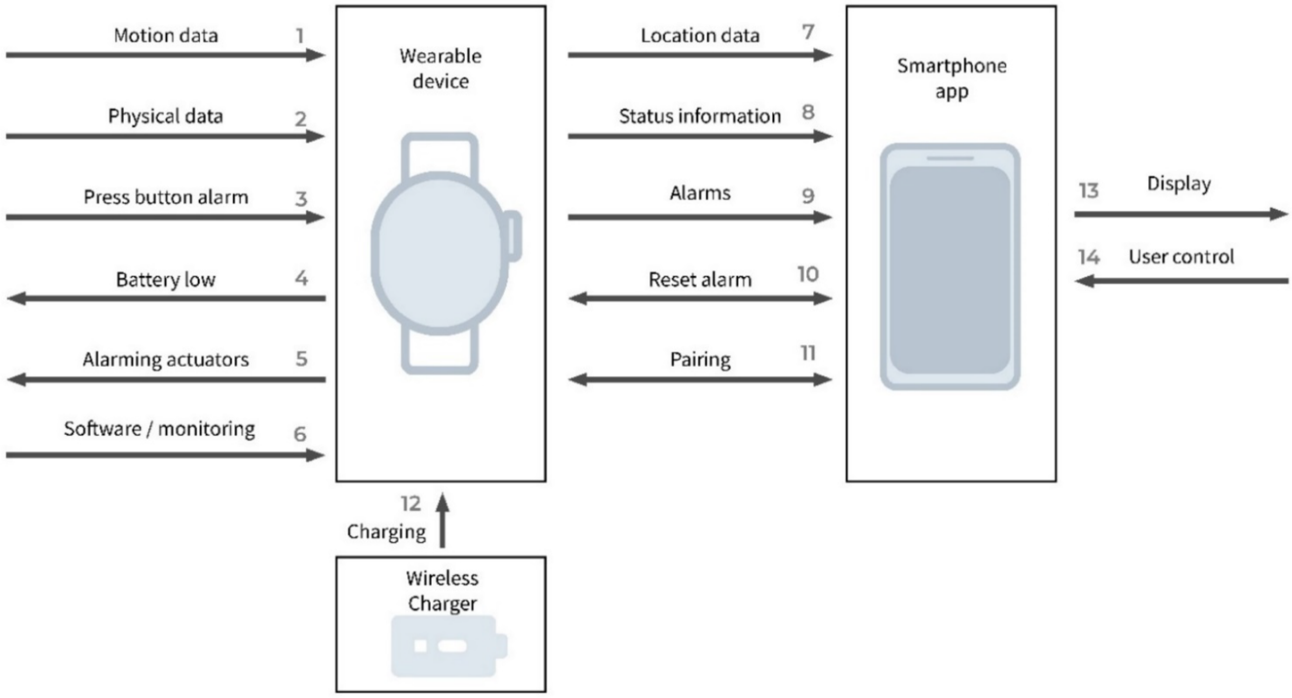


Figure 33: Product system overview

In the system overview figure 33, the system physical parts are indicated as black boxes and all functional interfaces between the system parts and the users are shown. Table 5 lists all functional interfaces of the system. This includes human physical parameter data, the motion data, the human machine interface and the technical interface between the technical system parts.

Table 5: Functional interfaces of the product system

Nr.	Interface	Description
1	Motion data	Acceleration, position and altitude of wearable device
2	Physical data	Heart beat and body temperature of the wearable device user
3	Press button alarm	User control of alarm button to set or reset alarm
4	Battery low	Indicator light on wearable device
5	Alarming actuators	Sound, light and vibrations
6	Software loading / updates / monitoring	Via LoRaWAN interface with Teneo-IoT BV
7	Location data	GPS data sent to the smartphone app
8	Status information	Status information from the wearable device to the smartphone app: battery low, charging, defects, not wearing device
9	Alarms	Manual alarm, automatic alarm, emergency push alarm
10	Reset alarm	On app, switch off alarm on wearable device
11	Pairing	Scan QR-code via camera of smartphone
12	Charge	Wireless charging

13	Display	Display information on the smartphone app
14	User control	User control of the smartphone app

6.1.2 Decomposition of system wearable device

In figure 35 the functional parts and processing of the wearable device are shown. The center of the system consists of the Teneo Nano (figure 34). The Teneo Nano is a generic standard building block developed by client company Teneo-IoT B.V. which makes it possible to easily realize various IoT-applications. Because various sensor protocols are standard part of the Teneo Nano and the firmware is prepared for this, sensors can be easily integrated on the Teneo Nano without an extensive R&D path. [65]

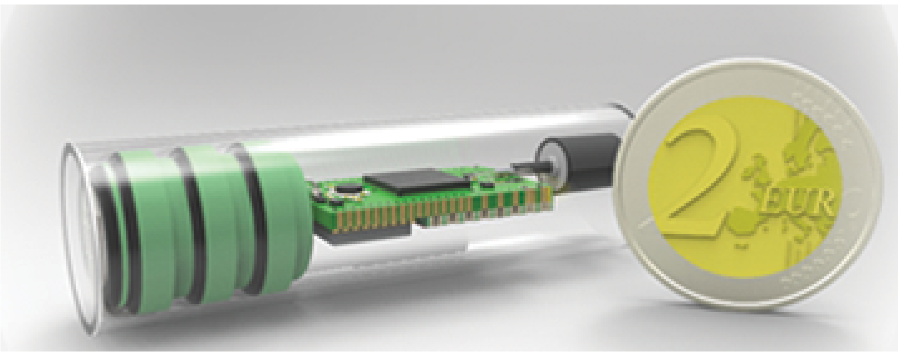


Figure 34: LoRa(WAN) module Teneo Nano [65]

In figure 35 the components indicated with a dark blue fill color are placed on the Teneo Nano. To detect a heart abnormality the Microprocessor Control Unit (MCU) processes the physical data coming from the heartrate sensor and temperature sensor. The incoming motion data is processed in the MCU to detect a fall. Furthermore the MCU processes the alarming function and the control of the actuators. The forwarding of the GPS data, battery status and all other bi directional communication is realized via the LoRaWAN interface. The following additional auxiliary parts are integrated in the wearable device: LoRaWAN antenna, rechargeable battery and the charging coil.

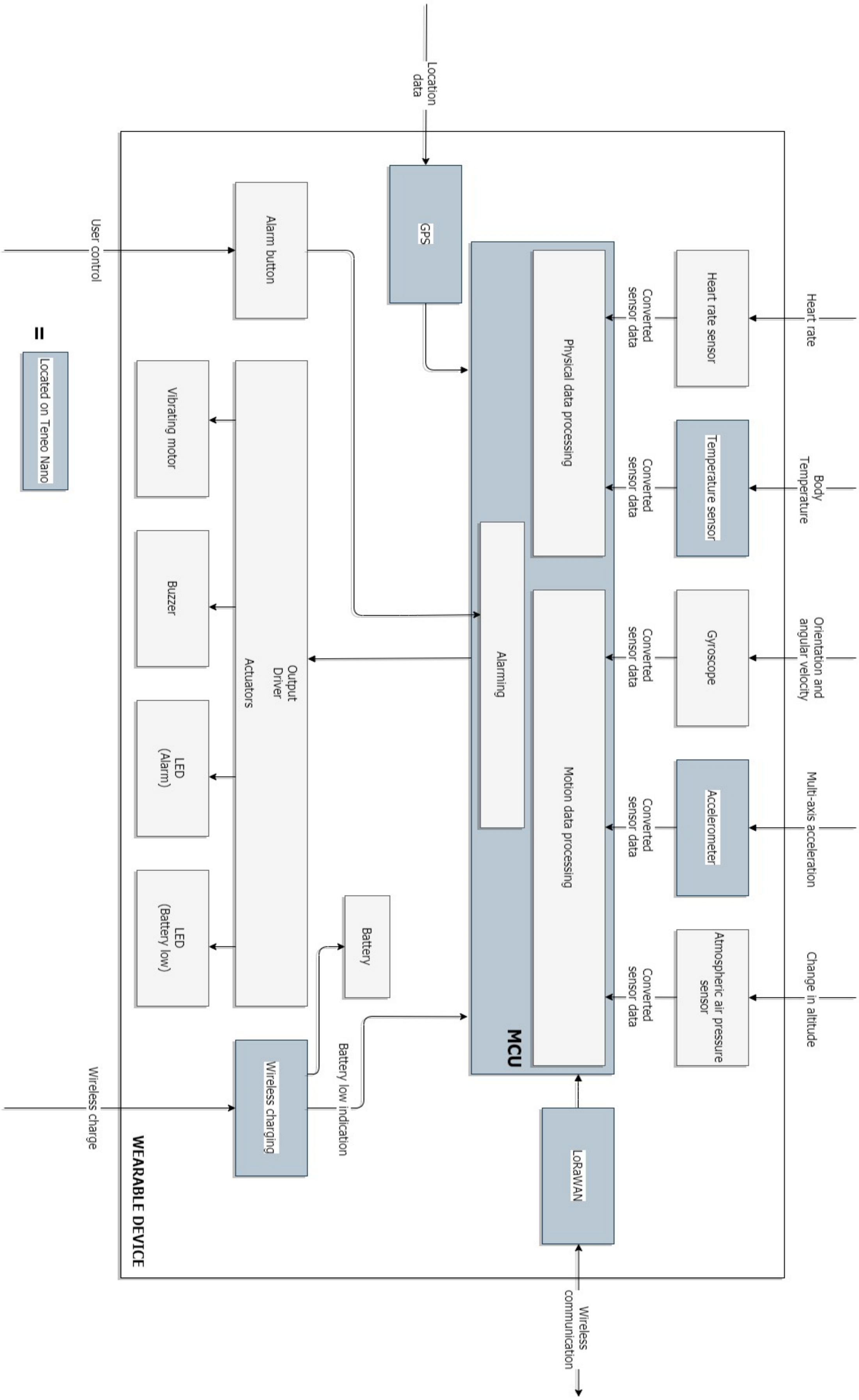


Figure 35: Physical parts of the wearable device

6.1.3 Functional flowchart

After describing the key functionalities, this section focusses at specific internal functions related to the alarming of the system. The alarming can be set in 3 ways:

1. *Automatic fall alarm: Activated automatically by the device in case of a fall*
2. *Manual personal alarm: Activated by the user*
3. *Emergency push alarm: Activated automatically by the device in case of heart abnormality*

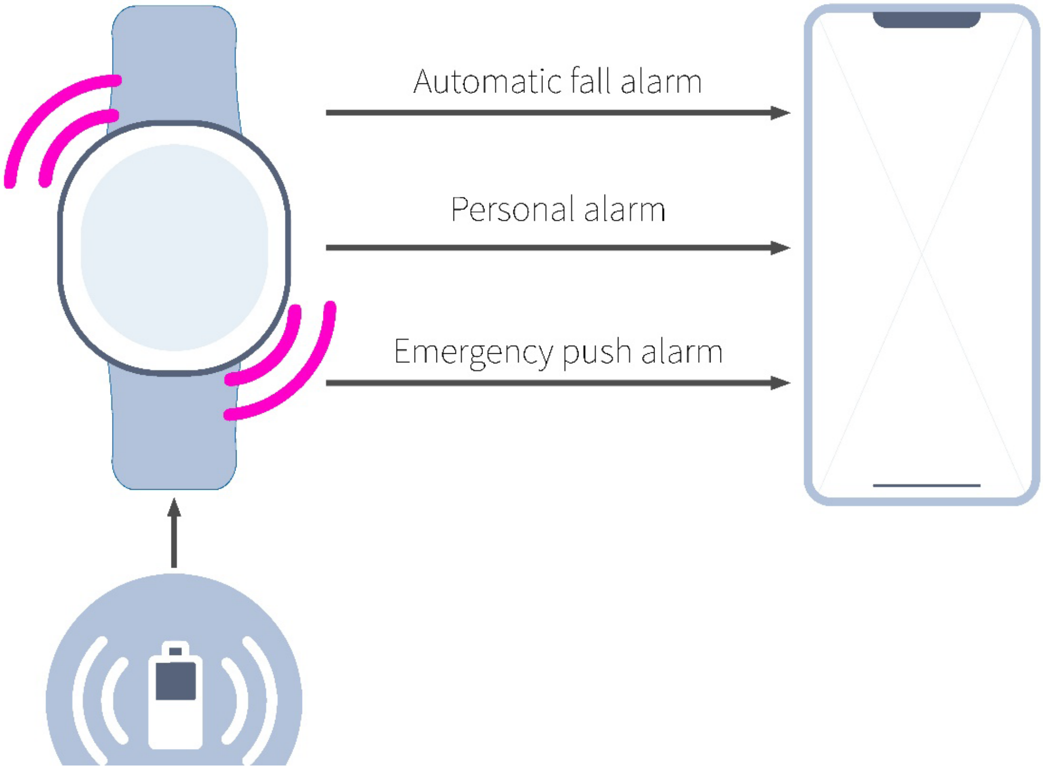


Figure 36: Three types of alarms

Automatic fall alarm

The functional flow of the wearable device in case of an automatic alarm is shown in figure 37. The automatic fall detection is only active if the wearable device is worn. The 'Battery charging' and 'Not Wearing device' status is always sent to the app if these conditions are true. When the Motion Data Processing detects a fall the buzzer, LED and vibration will start simultaneously. If the alarm button is pressed within 10 seconds the buzzer, LED and vibration will be switched off and no alarm is sent to the app. If the alarm button is not pressed within 10 seconds an alarm is sent to the app the buzzer, LED and vibration will stay activated until a reset alarm message is received from the app (initiated by the person who has accepted to provide assistance in the app).

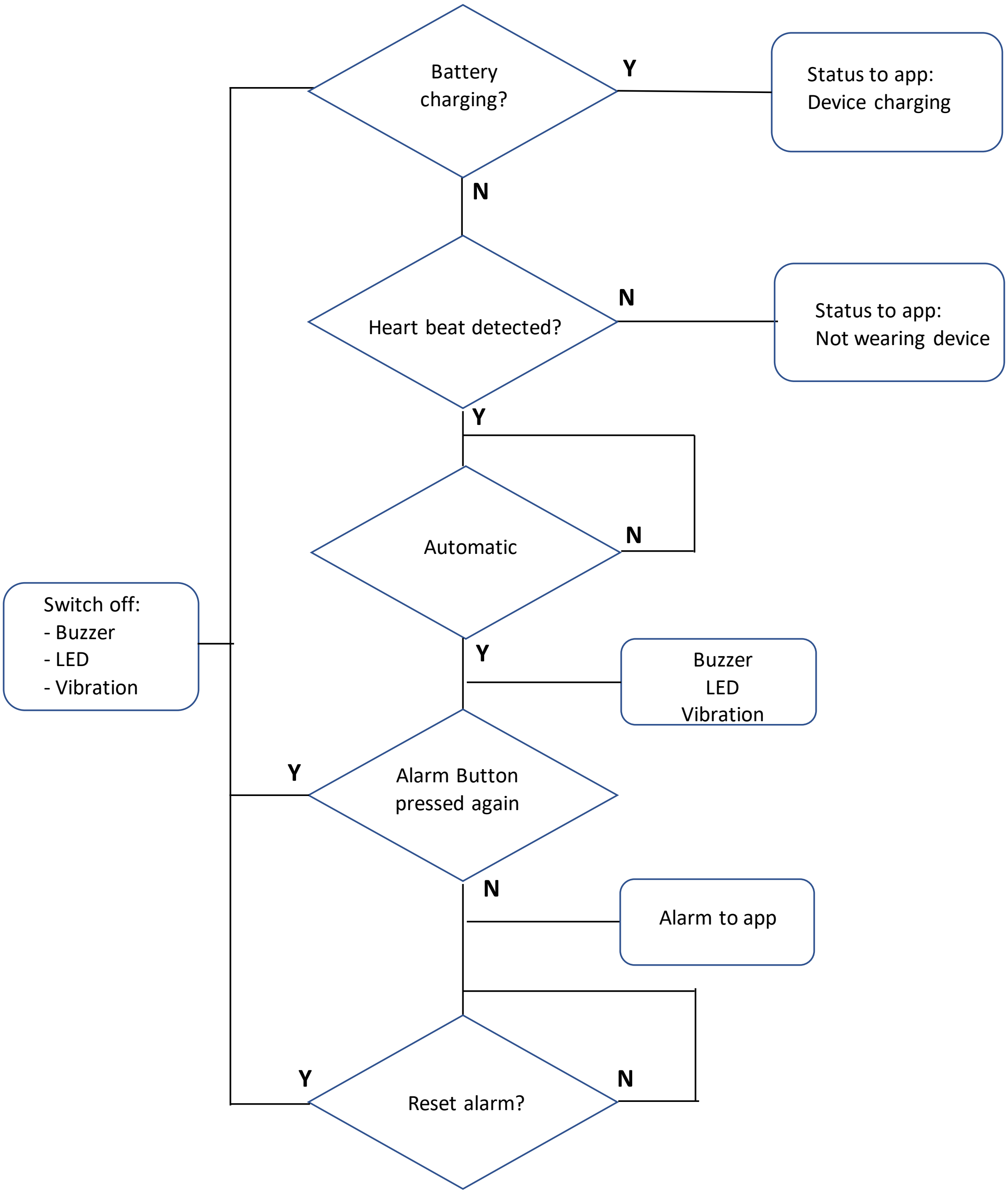


Figure 37: Functional flow of the wearable device in case of an automatic alarm

Manual personal alarm

The functional flow of the wearable device in case of a manual alarm is shown in figure 38. If the alarm button is pressed (also in case the wearable device is not worn) the buzzer, LED and vibration will start simultaneously. If the alarm button is pressed again within 10 seconds the buzzer, LED and vibration will be switched off and no alarm is sent to the app. If the alarm button is not pressed again within 10 seconds an alarm is sent to the app the buzzer, LED and vibration will stay activated until a reset alarm message is received from the app (initiated by the person who has accepted to provide assistance in the app).

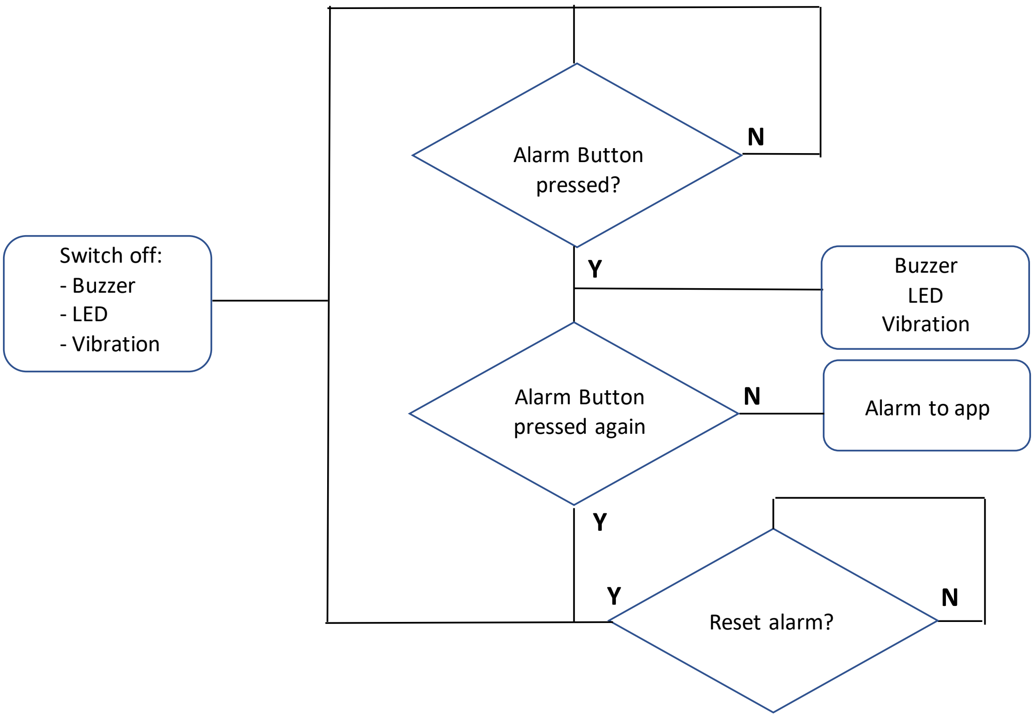


Figure 38: Functional flow of the wearable device in case of a manual alarm

Emergency push alarm

The functional flow of the wearable device in case of an emergency push alarm is shown in figure 39. The heart abnormality detection is only active if the wearable device is worn. The 'Battery charging' and 'Not Wearing device' status is always sent to the app if these conditions are true. When the Physical data processing detects a heart abnormality (too high, too low and/or fibrillation), the buzzer, LED and vibration will start simultaneously. A push is send directly to the app and the buzzer, LED and vibration will stay activated until a reset alarm message is received from the app (initiated by the person who has accepted to provide assistance in the app).

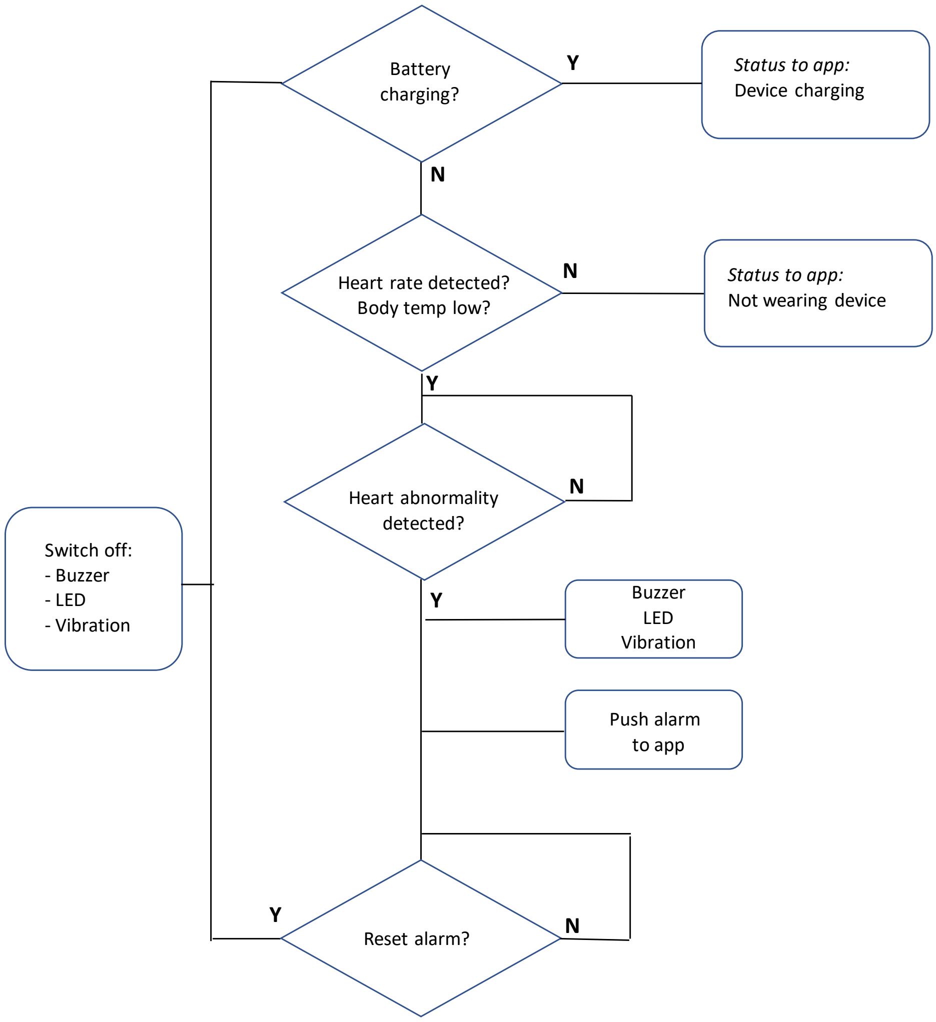


Figure 39: Functional flow of the wearable device in case of an emergency push alarm

6.1.4 External interfaces

Wireless communication

For the communication between the wearable device and the smartphone app the LoRaWAN wireless communication network is used. [66] LoRaWAN is a Low Power Wide Area Network (LPWAN), specially developed for wireless, battery-operated products in a regional, national or global network. The usage of LoRaWAN is a requirement from Teneo-IoT B.V.

The LoRa network consists of a network of antennas (Radio Gateways) and the LoRaWAN Cloud (server). The Radio Gateway forwards all received LoRaWAN radio packets from the wearable device to the Network Server. All application layer data of the wearable device is routed to its corresponding Application Server. The Radio Gateway operates entirely at the physical layer. Its role is simply to decode uplink radio packets from the air and forward them unprocessed to the Network Server. Conversely, for downlinks, the Radio Gateway simply executes transmission requests coming from the Network Server without any interpretation of the payload.

As soon as a LoRa message is received by a gateway, it will forward the message to the LoRaWAN Cloud. This LoRaWAN Cloud can be configured, via a website, to forward the LoRa messages to its own server. In this case, this own server is a WampServer. A WampServer is a server that runs on Windows and is a combination of Apache, MySQL and PHP. This combination makes it possible to create a database containing tables of data. The data in these tables can be removed, replaced, placed or read by an application. After receiving a LoRa message, the LoRaWAN Cloud will request the server to place the data in the table. During this request, the server will check a number of things, such as whether the correct data has been sent in the request. After this check, data will be stored in the table.

As the LoRaWAN data transmission is not very reliable, the LoRaWAN Cloud will send a 'Acknowledge' message to the wearable device after each correct message received from the wearable device. If the wearable device does not receive an 'Acknowledge' message after sending a message to the LoRaWAN Cloud, the wearable device will send the same message again and again until a 'Acknowledge' message has been received by the wearable device.

LoRaWAN has three different classes of end-point devices to address the different needs reflected in the wide range of applications: Class A, B and C. For this project Class A is chosen, because this class has the lowest power consumption. The low power consumption of the wearable device is important because it minimises the time the person is not wearing the device because of battery charging. In this class the wearable device is able to enter low-power sleep mode for as long as defined by its own application: there is no network requirement for periodic wake-ups. This makes class A the lowest power operating mode, while still allowing uplink communication at any time.

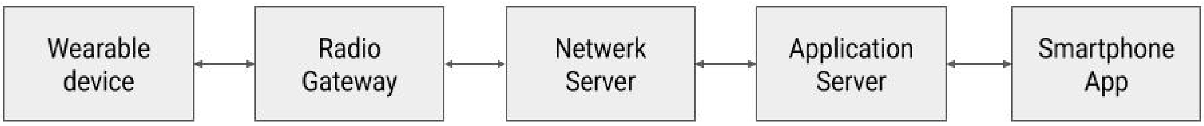


Figure 40: LoRaWAN network

LoRaWAN offers several benefits:

- Long communication distances (up to 30 kilometers). This enables the outside door use and geofencing (going for a walk only within a demarcated area).
- Low power consumption / long battery life. This minimizes the time not wearing the wearable device due to charging.
- Bi-directional communication needed for reset-, data request messages and software (updates) loading to the wearable device.
- "Open Source" protocol 'Open Source' protocol, making it possible to set up your own "private" network;

Interfaces between the wearable device and the app

The diagram (figure 41) shows all functional blocks of the wearable device and all functional data messages between the wearable device, the smartphone app and Teneo-IoT via the LoRaWAN.

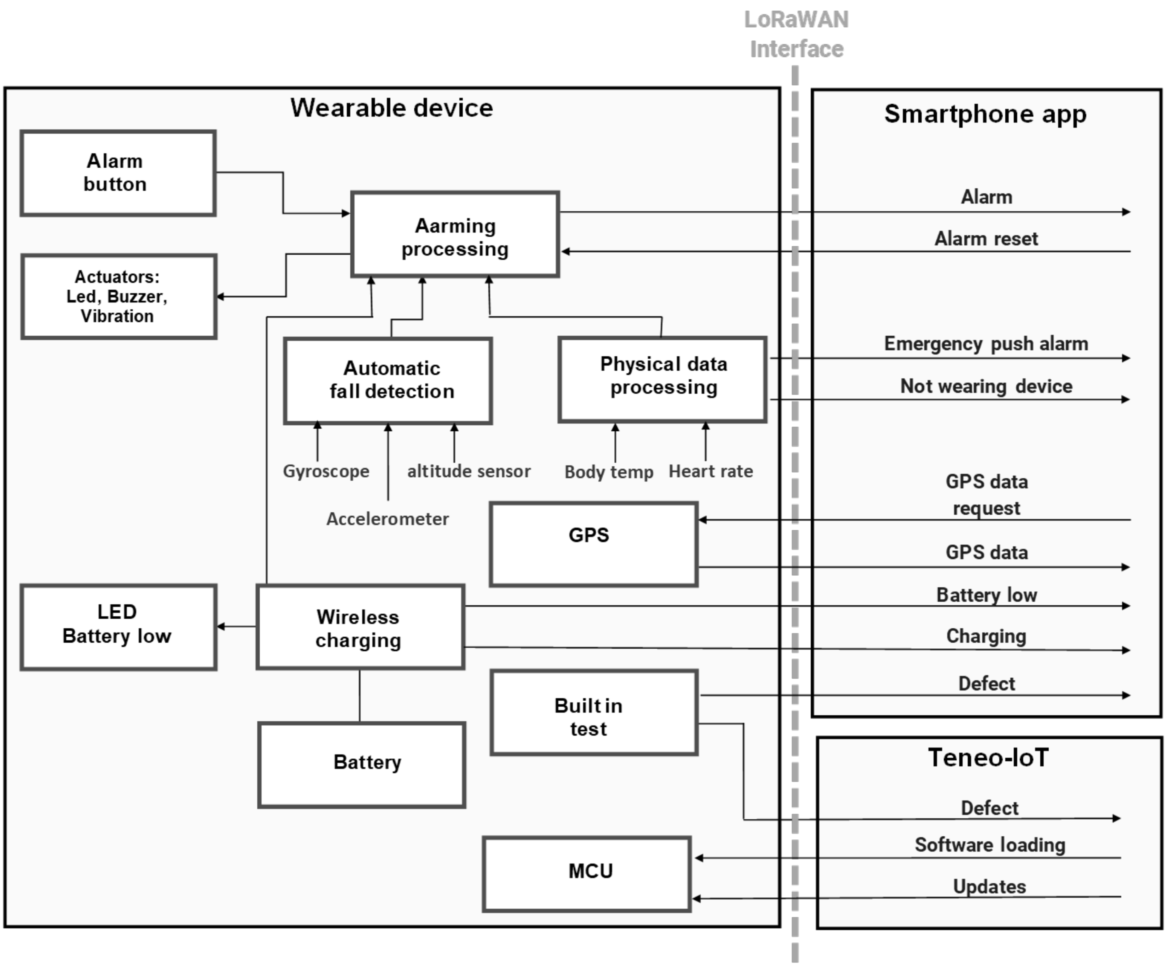


Figure 41: Physical diagram with LoRaWAN interface

In table 6 the data messages between the wearable device, the app and Teneo-IoT B.V. via the LoRaWAN are described. The possible values of the data in the messages are specified in the right column of table 6.

Table 6: Data messages via the LoRaWAN and the possible values.

Name	Explanation	Values in table
Alarm	- **TRUE** in case of an Alarm message received from the wearable device. Alarm message is send to app immediately after the alarm processing in the wearable device generates an alarm. - **FALSE** after an Alarm reset message received from app.	TRUE, FALSE
Alarm reset	- **TRUE** in case of an Alarm reset message is received from the app.	TRUE, FALSE

	- Set to **FALSE** after the alarm has stopped and an Alarm reset message sent to wearable device by app.	
Emergency push alarm	- **TRUE** in case of an Emergency push alarm. Emergency push alarm is send by the wearable device immediately after detection of an emergency. - **FALSE** after an Alarm reset message received from app.	TRUE, FALSE
Not wearing device	- **TRUE** after 'Not wearing device is true' sent by wearable device. - **FALSE** after 'Not wearing device is false' message is sent by wearable device.	TRUE, FALSE
GPS data request	- GPS data request send to wearable device in case GPS data is needed by the app (in case of an alarm or geo-fencing). - Set to **FALSE** after GPS data has been received.	TRUE, FALSE
GPS data	- GPS data sent on request from wearable device to app.	Latitude (DMS format) Longitude (DMS format)
Battery Low	- **TRUE** after 'Battery Low true' is sent to the app when battery time is less than 24 hours. - **FALSE** after 'Battery Low false' is sent to app.	TRUE, FALSE
Charging	- Set to **TRUE** when 'Charging is true' message is sent to app. - Set to **FALSE** when 'Charging is false' is sent to app.	TRUE, FALSE
Defect to App	- Set to **TRUE** in case of a 'Defect true' after a defect detected by the built in test in wearable device. - Set to **FALSE** after a 'Defect false' message from wearable device.	TRUE, FALSE
Defect to Teneo-IoT	Report defect part to Teneo-IoT. In case of a defect the status for the defect part is **TRUE**. The parts are: - Heart rate sensor - Temperature sensor - Gyroscope - Accelerometer - Air pressure sensor - GPS - Wireless charging	TRUE, FALSE for each part separately

6.1.5 Wireframe user flow of smartphone app

In this section, the different parts of the smartphone app will be described and the actions the users have to perform to access the different sections of the smartphone app. This will be done by using a wireframe user flow. Figure 42 shows the total wireframe user flow of the app. The wireframe user flow is mapped in different sections (login, alarm, status, service and account based on tasks / functions that connect. As shown in figure 42, there is one central home dashboard from which the different functions can be selected. The different sections will be explained below.

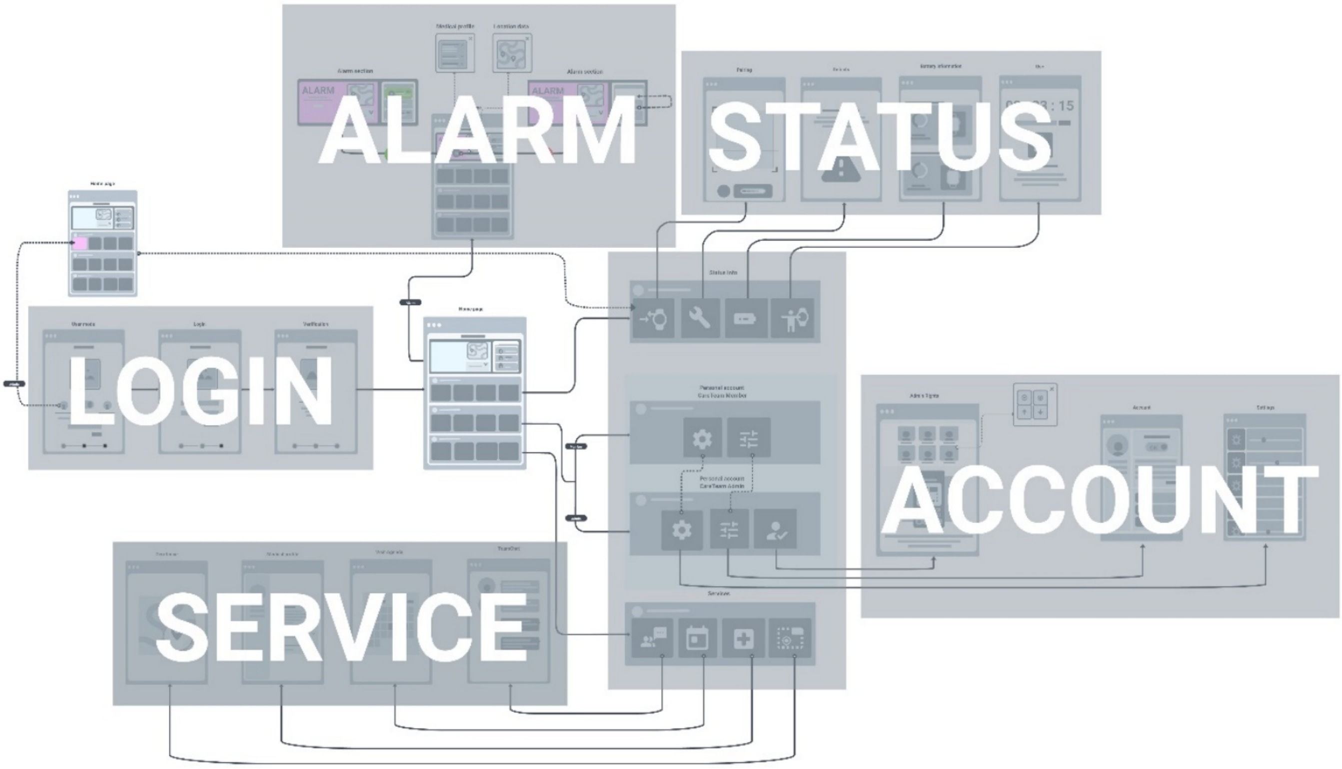


Figure 42: Overview complete wireframe user flow

Login

When purchasing the product, a certain number of product / subscription codes will be released for the app. These license codes are linked to the wearable device.
After the carer has downloaded the smartphone app, the carer will enter the login section (figure 43) of the app. At the first use of the app this login procedure consists of the following steps: choosing the "user-mode", "sign-in", "verification of account" and "user onboarding".

- *User-mode*

Here the user enters one of the released license codes and indicates whether he wants to login as "Admin" or as a "Member". If the user logs in as admin, he will have special rights and responsibilities. Per purchased product, only one of the supplied license codes can be used for an admin account. Depending on whether the user logs in as an admin or member, he will receive a different user onboarding and home dashboard. For example, the admin will first be given the task of linking the wearable to the smartphone app.

- *Sign in*

Here the user enters his e-mail address and a username and password of his choice. A verification code will be sent to the email address.

- *Verification*

Here the user enters the verification code to complete the login process.

- *User onboarding*

Onboarding is defined as a way to introduce an app, demonstrate what it does and making someone familiar with an app. Progressive onboarding will be used in this app; which is a learning program which presents information to users as they use the app for the first time. The onboarding will show the user <u>what</u> the key functionality is, <u>when</u> this functionality should be used and <u>how</u> this functionality will be used.

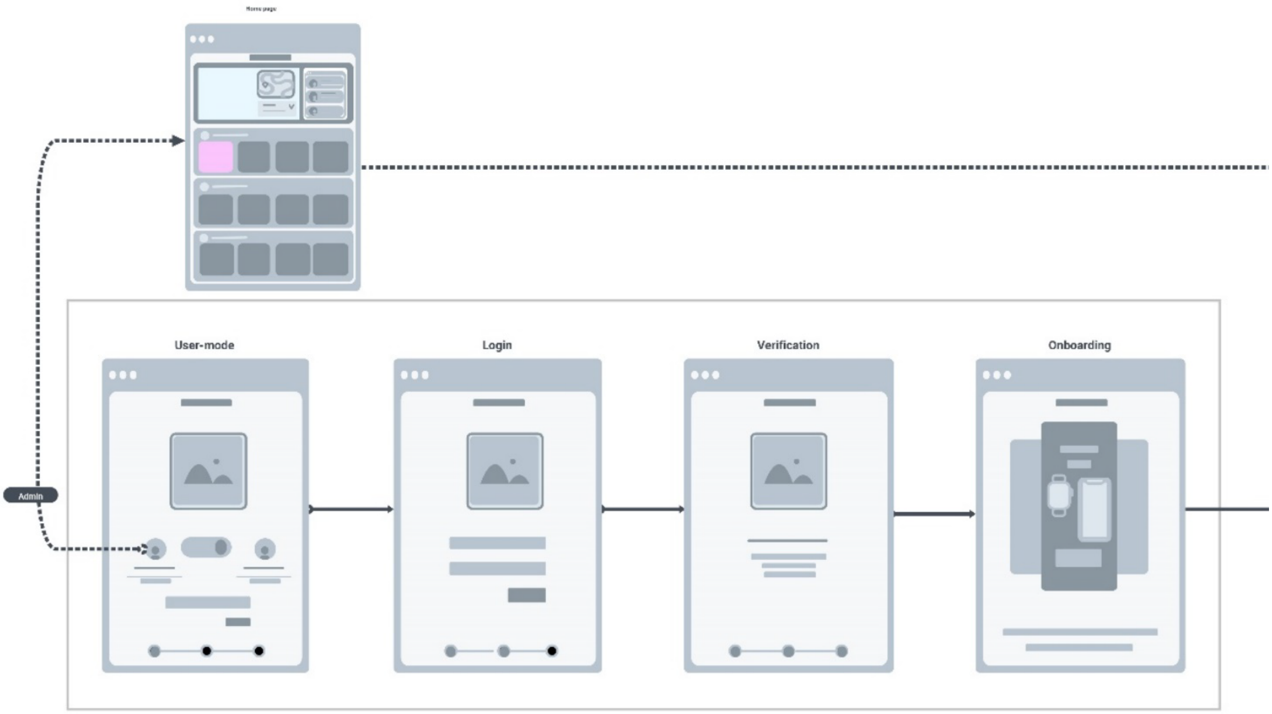


Figure 43: Login section (user-mode, login, verification, onboarding)

Home dashboard

After completing the login procedure, the user will see the "home dashboard" (figure 44). The "home dashboard" consists of 4 parts; at the top the alarm section and below three blocks in which the other app functions are grouped. The three groups are: status information of the wearable, personal account and services. These three groups again consist of different functions, indicated by the icons shown in figure 44. From any linked screen, the user can return to the "home dashboard" with one click.

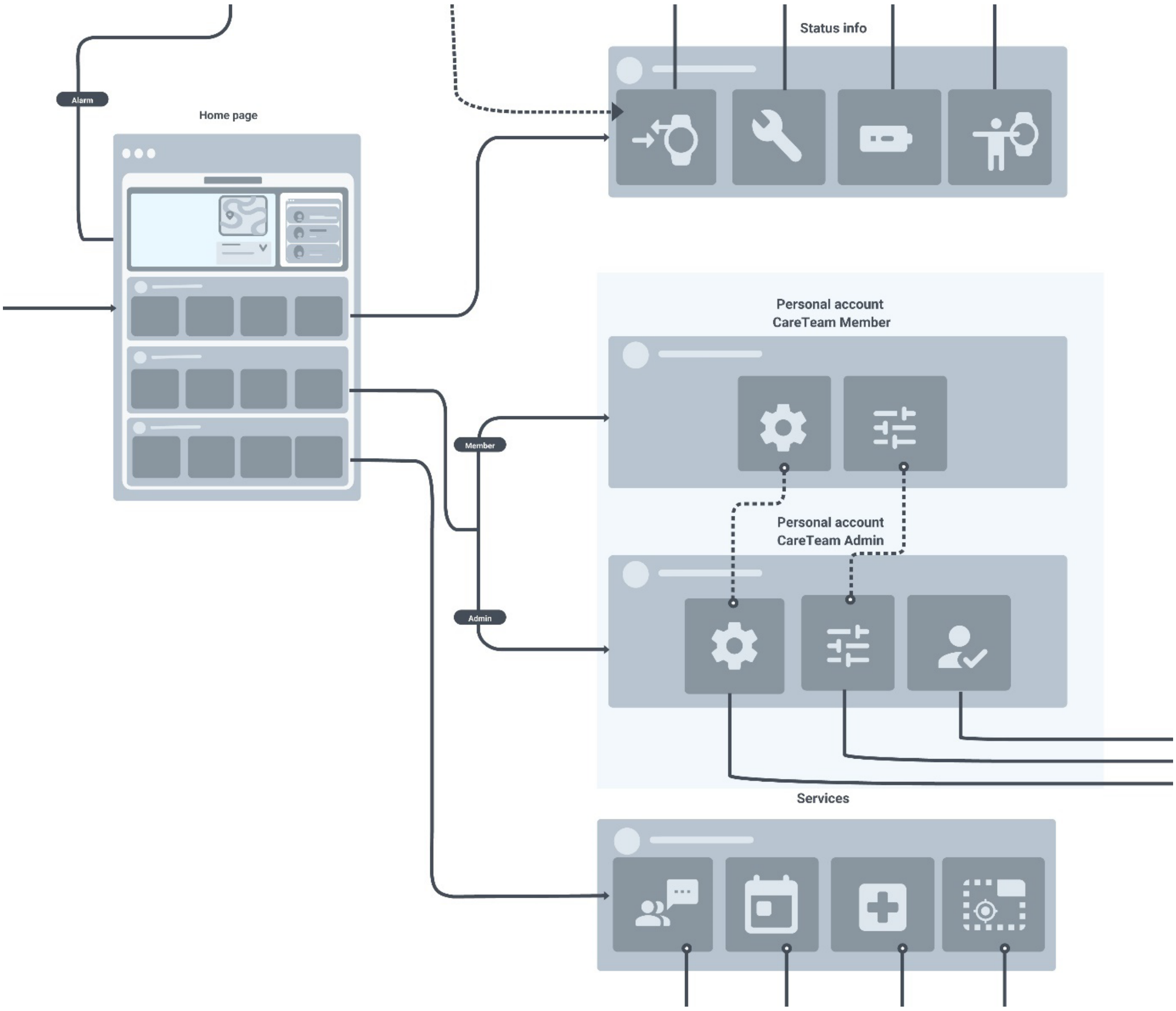


Figure 44: Section wireframe home dashboard (alarming, status information, account, services)

Alarm

The alarm section will be visible on every screen in the app at all times, also if there is no alarm at the moment.

- *No alarm*

If there is no alarm, the alarm section is colored blue and "minimized" presented at the top of the screen. In this situation, the alarm section only contains the "carers list". The "carers list" is a list in which all carers of the user of the wearable device are included. The order of the list shows the sequence in which is asked to provide care in the event of an alarm. The order can be changed by the Admin. The "carers list" also shows who has access (key) to the wearable device user's home, whether someone has access to AED and whether someone has his availability "on" or "off".

- *Alarm*

If an alarm is issued from the wearable device, the smartphone app goes into "alarm mode" (figure 45). The alarm section will "expand" and the color will change. The screen also shows that an alarm has been issued. In the settings users can set how they want to be alarmed (sound, push notification, vibrations, etc.). First of all, the screen shows the type of alarm involved (manual alarm, automatic alarm and emergency push alarm). In addition, the location of the wearable device user can be seen. The top user in the "carers list" will be notified and be asked whether this person is available to provide care.

→Situation: YES

The user in the list changes color (purple) so the other users can see the top user in the list is able to provide care at the moment. The user is currently given access to the medical file of the wearable device user (by permission). The telephone number of the user of the wearable device is now also displayed. Once the user has provided care and / or brought the wearable device user to safety, he can manually reset the alarm, so the other users know the situation has been resolved.

→ Situation: NO

The user in the list changes color (gray) and is returned from the highest position in the list to the bottom position in the list. The next person in the list will now receive the message asking if this person is currently available to provide care. This process continues until someone has indicated to be able to provide care. If someone does not respond to the notification within 60 seconds, the notification also automatically advances to the next person in the list.

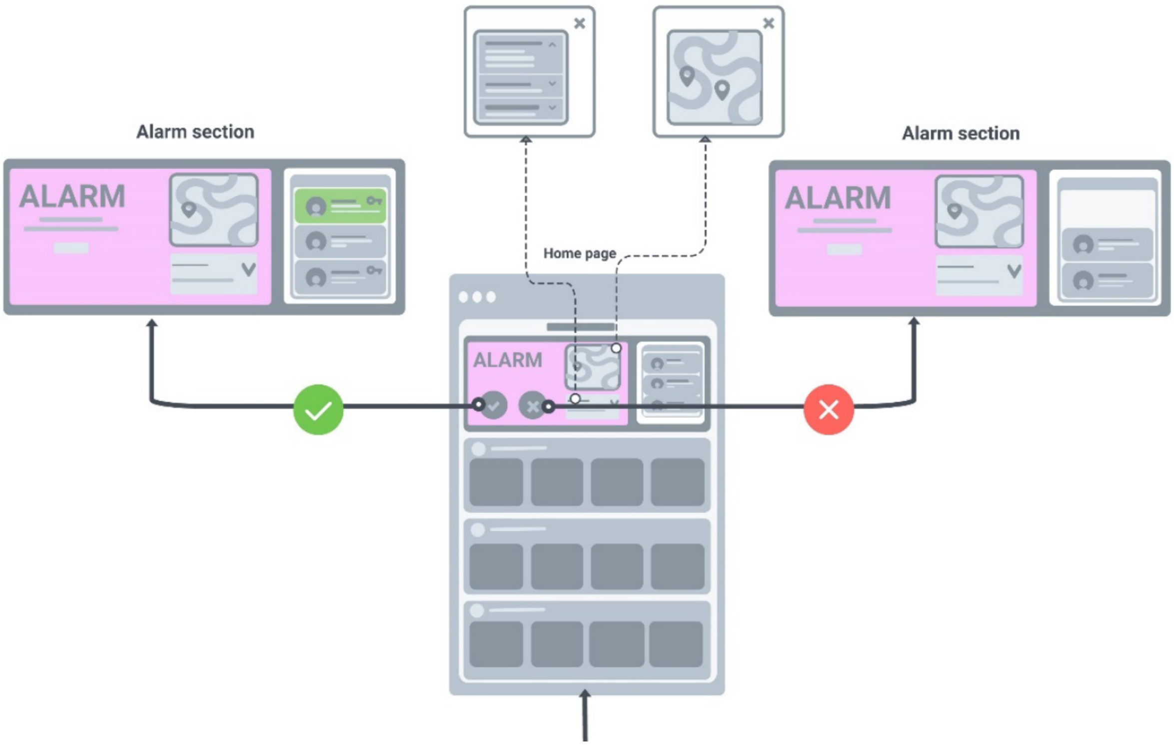


Figure 45: Section wireframe alarm situation (available, not available)

Status information

The block "status information" on the screen "home dashboard" shows information about the wearable device and consists of four parts: pairing, defects, battery, information.

- *Pairing*

When the product is used for the first time pairing of the wearable device with the smartphone app will be done by the Admin. Pairing the wearable device with the smartphone app is done by scanning a supplied QR code. From that time this screen shows whether the wearable device is still paired. If the wearable device is no longer connected, this pairing can be done again.

- *Defects*

As soon as a defect in the wearable device is detected by the 'built in test', this will be reported to the app. Teneo-IoT will receive detailed information about the defect.

- *Battery information*

Here the user can see the battery status. In case of "battery low", the carer can inform the wearable device user (who also receives a warning by the LED 'Battery Low' on the wearable device) or help the wearable device user with charging.

- *Use*

Here the carer can see whether the wearable device user is wearing the wearable or not and if the person is not wearing it. Also is shown whether it is because the wearable device is loading. The user can also see here how long the wearable has not been worn.

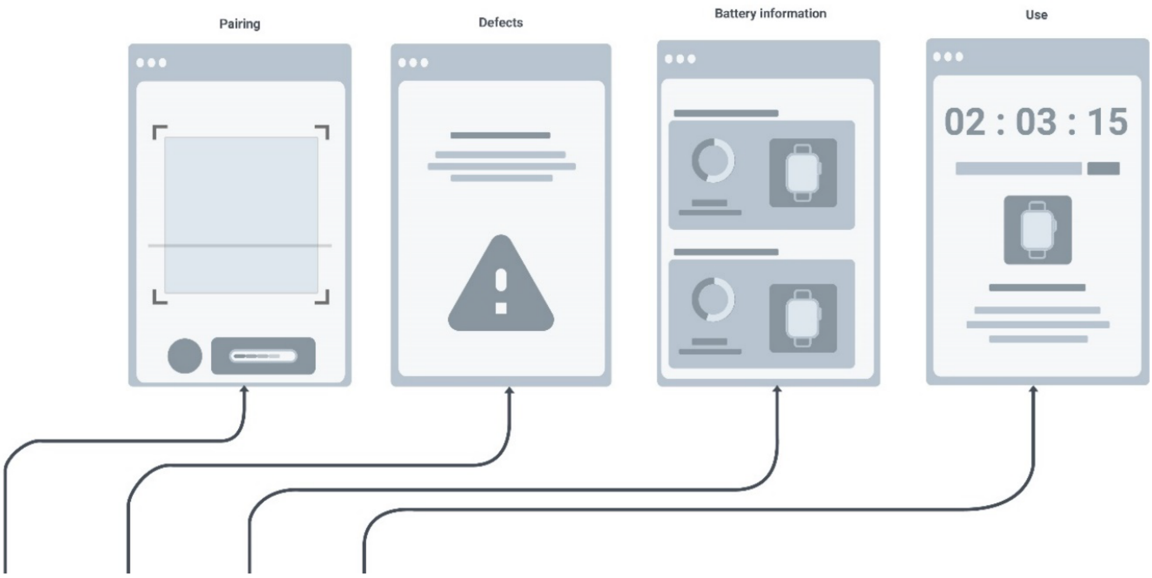


Figure 46: Section wireframe user flow status information (pairing, defects, battery information, in use)

Services

The smartphone app offers 4 services (figure 47), namely geofencing, medical profile, visit agenda and a team chat.

- *Geofence*

The geofence service is a location-based service in which the smartphone app uses GPS data to trigger a pre-programmed action when the wearable device enters or exits a virtual boundary set up around a geographical location, known as a geofence. Deze geofence kan alleen ingesteld worden Admin. De admin kan ook bepalen of deze service zichtbaar is voor de rest van de gebruikers. This geofence can only be set by the Admin. The Admin can also determine whether this service is visible for the other users.

- *Medical profile*

In the medical profile section, the admin can, with the permission of the user of the wearable device (see section 8.3 for related privacy ethics), add information about medication, known conditions and appointments. The other users can also see this only after the permission of the admin. This part of the smartphone app will be extra secured by, for example, a code or touch ID.

- *Visit agenda*

Visiting appointments with the wearable device user can be scheduled and the carers can see each other's appointments in the app.

- *Team chat*

In this chat box carers can communicate with each other.

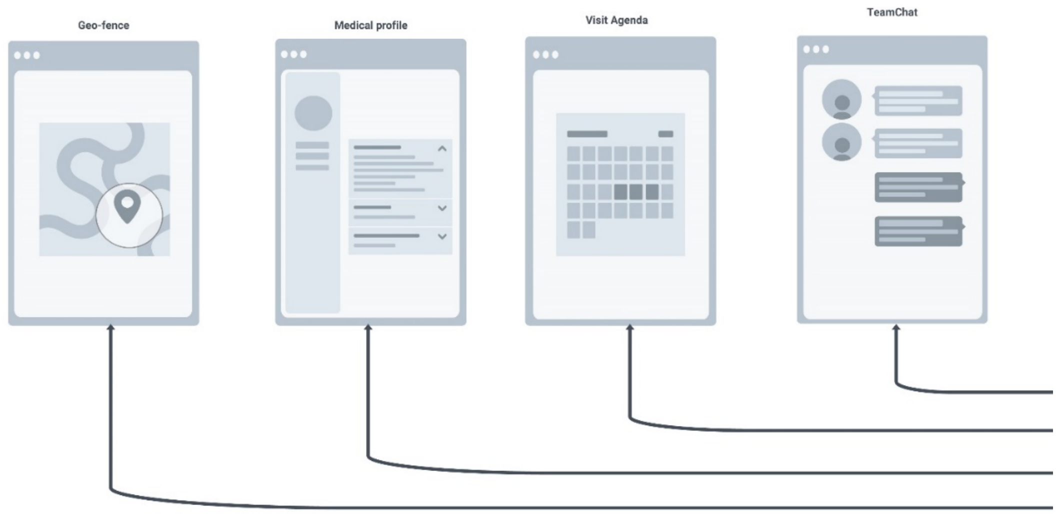


Figure 47: Section wireframe services (geofencing, medical profile, visit agenda, chat)

Account

The section "account" (figure 48) is different for admin and members. Both can change their personal profile and settings in this section. The admin has the additional option of setting the "admin rights".

- *Personal profile*

The user can adjust items like username, profile picture and phone number here. The user can also set his availability to “ON” or “OFF” here. The user can also indicate here whether he or she has access to the home of the wearable device user and whether the person has access to an AED. These things will be visible to the other users in the "carers list".

- *Settings*

Here the user can change the app settings. These are things like the color theme, way of alerting (sound, vibrations, push notification etc.), font size, language and privacy settings.

- *Admin Rights*

This section is only visible to the Admin. On this page the Admin can make changes to the "carers list". This allows him to prioritize, remove and add carers within the list. Furthermore, the Admin can set the geofence here and determine who has access to the medical file.

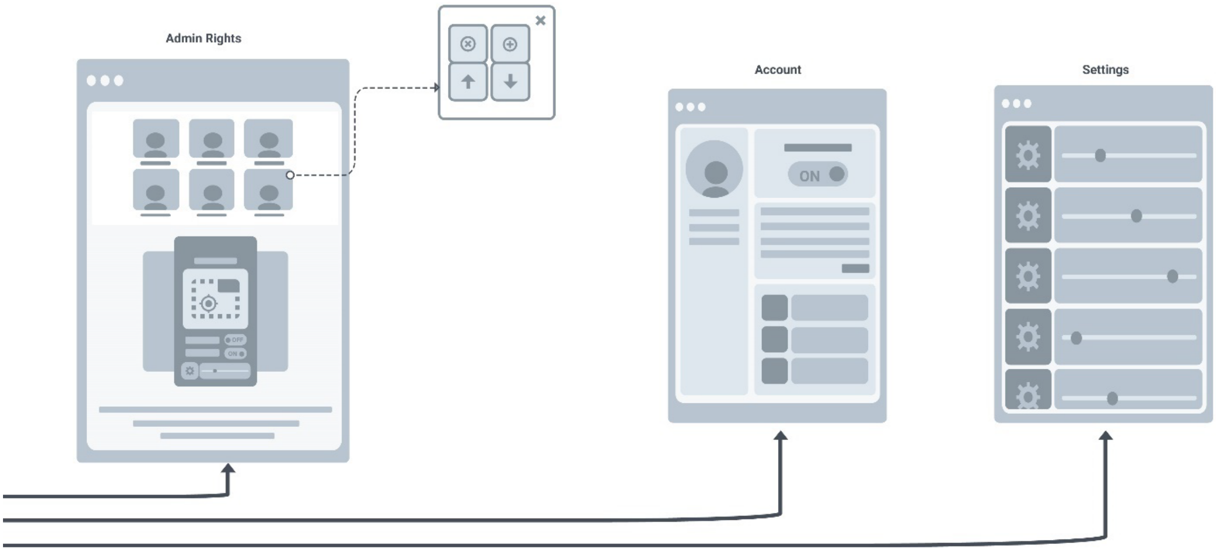
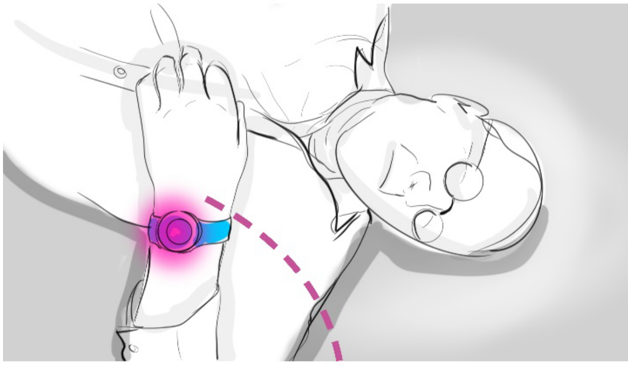


Figure 48: Section wireframe showing account settings (admin rights, account, settings)

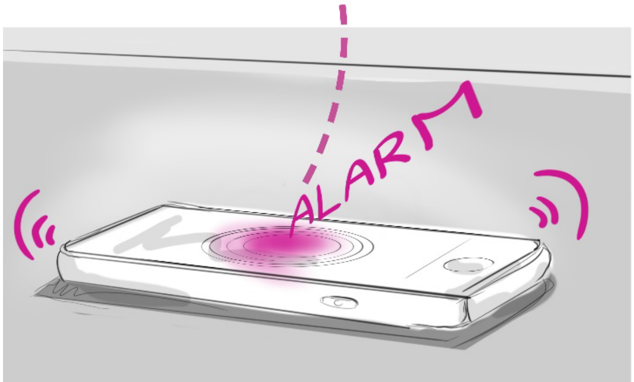
6.2 Scenario [2] User journey storyboard

The description of the design above mainly focuses on the technical aspects of the design. In order to see how a user would interact with the product, a user journey storyboard was created. The storyboard shows how the product can be used in emergency situations. This is one of the most important user scenarios for this product.

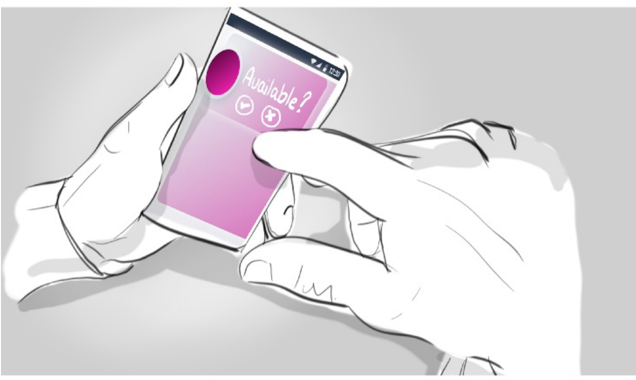
The user of the wearable device has fallen



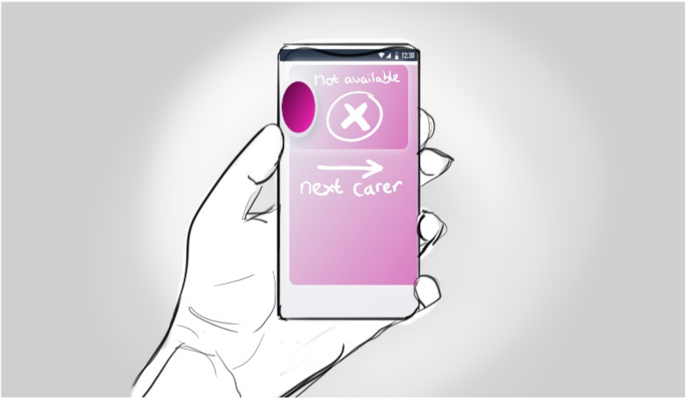
Fall detected: alarm is sent to the smartphone app



Alarming notifications on smartphone are activated



First person on list is asked if he is available to provide help



Person on the carers list is not available. Alarm is forwarded to the second person on the carers list

Second person on the carers list accepts the alarm

Person goes to location of the fall to help the wearable device user.

Person tries to call the user of the wearable device, but he is not able to pick up the phone

Figure 49: User journey storyboard. Use case: fall accident.

6.3 Final requirements

The preliminary requirements formulated during the ideation are analyzed with the SMART method and re-evaluated based on the new insights gained during the specification. The functional system architecture and further diagrams resulted in additional functional and non-functional requirements which are added to the list. This resulted in the final requirements which can be found in Appendix E. The additions and modifications on the preliminary requirements can be found in the table below.

Table 7: adjusted and added requirements

MUST			
Functional Requirements	**W**	*M1.1*	It MUST be possible to place the wearable device in ***different supporting wearing systems.***
	W	*M1.2*	***The wearable device MUST be a modular interchangeable module that can be placed in different supporting wearing systems without using any tools.***
	W	M4	If after detecting a (possible) fall / emergency the user has not interacted with the wearable device within ***10 seconds*** an alarm MUST automatically be sent to the corresponding smartphone app.
	W	*M5.1*	*If no heart rate or heart rate abnormalities are detected by the wearable device **during 20 seconds**, an emergency alarm MUST be issued.*
	A	*M5.2*	***In case of an emergency alarm** a push notification MUST be send to the smartphone app users who have a resuscitation competence and/or access to an AED.*
	W	*M6.1*	*The user MUST be able to control the wearable device by **a momentary push button***
	P	M7.2	*Low battery indication MUST be true when the operating time **is less than 24 hours.***
	A	*M8.1*	*If there is no response of the smartphone-app user who is alerted in case of an emergency **within 60 seconds**, the next person in the predefined list MUST be alarmed.*
Non-functional Requirements	**W**	*M13.1*	*The wearable device MUST have a battery **low** status indicator.*
	W	*M13.2*	***Battery low status MUST be true in case less than 24 hours of operation time is left.***
	W	*M13.3*	***In case of battery low, the wearable device MUST generate every 8 hours an acoustic-, vibration- and light signal during 5 seconds until the wearable device is connected to the wireless charger.***
	W	*M13.4*	***In case the wearable device is placed on the wireless charger and the battery is charged to maximum capacity the wearable device MUST generate every 60 seconds an acoustic-, vibration- and light signal during 5 seconds until the wearable device is put on the wrist.***
	W	*M13.5*	***The wearable device MUST be fully recharged within 1 hour.***

	w	*M13.6*	*The battery of the wearable device MUST guarantee* ***an operation time of 72 hours.***
	P	M15	**LoRaWAN** MUST be used for software loading, software updates and product settings.
SHOULD			
Functional Requirements	**W**	S2.1	***It SHOULD be possible to lock the wristband. The locked wristband can only be put off with the help of a carer.***
Non-functional Requirements	**W**	*S6.2*	*The weight SHOULD not exceed* ***50 gram****.*
	W	*S6.4*	***The size SHOULD not exceed 40 mm diameter and height 15 mm***
	P	*S7*	The selling price of the product including wearable device, wireless charger and ***6 accounts*** *for the* smartphone-app SHOULD ***not exceed €500****.*
COULD			
WON'T			

CH 7_ Realization

This chapter describes the realization phase of the project. It describes how the requirements from the specification phase are implemented. This chapter is split into two parts: the implementation of the wearable device and the implementation of the smartphone app. Furthermore this chapter describes the realization of the technical model of the wearable device and a mock-up of the smartphone app.

7.1 Wearable device

This section describes the realization process of the wearable device. First all components will be described, then it will be explained how the sensors will be used to detect a fall. After this some design details will be given and then how this is integrated in a technical product model.

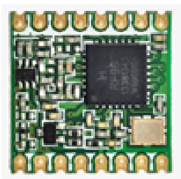
7.1.1 Hardware components

The decomposition of the requirements to component level results in detailed functional requirements for the components. For the design of the technical detailed model (see section 7.3) complementary requirements for the shape of the components and exact dimensions are added.

Hardware on Teneo Nano

The Teneo Nano is the heart of the wearable device. All processing is performed by the MCU (Microprocessor Control Unit) on the Teneo Nano. Below the components (besides the MCU) integrated on the Teneo Nano are listed. A detailed table of all components can be find in Appendix H.

LoRaWAN

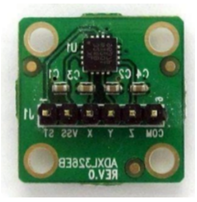


LoRaWAN is a Low Power Wide Area Network (LPWAN) used for the interface between the wearable device and the smartphone app and Teneo IoT. The used module is specially developed for wireless battery-operated products.

GPS Receiver

The GPS receiver information is used for location determination and geofencing. It has an embedded Patch Antenna and LNA. It is characteristic of low power consumption and compact size.

Accelerometer

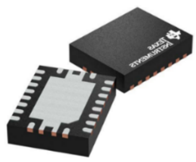


The accelerometer is used to measure acceleration. The 3-axis acceleration information, combined with information from other sensors is used to determine if someone is falling. The used accelerometer module is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum to full-scale range of ±3 g.

Temperature sensor

The temperature sensor measures the body temperature to help to determine if the device is worn. on the wrist. The sensor is housed in a TO-92 casing. Operating temperature: -40 - +126 °C and has 10 mV/°C scale factor.

Wireless charging

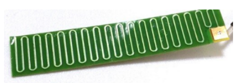


For battery charging a highly integrated wireless receiver is used. The Wireless Receiver is connected to a charging coil with ferrite which is not integrated on the Teneo Nano board.

Auxiliary parts

Besides the Teneo Nano the other auxiliary parts must be packaged in the housing in efficient way so the wearable device does not become bulky and fits on the wrist of a fragile person. Below, the components connected to, but not integrated on the Teneo Nano board are listed. A detailed table of all components can be find in Appendix H.

LoRaWAN antenna

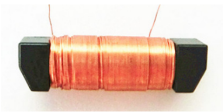


The LoRaWAN has an additional PCB antenna.

Rechargeable Battery

The battery largely determines the volume and layout of the wearable device. The selected battery is a rechargeable coin cell battery 3V, Lithium Manganese Dioxide, 620 mAh.

Charging coil

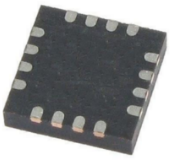


A charging coil with ferrite is needed for the wireless battery charging.

Pressure Sensor

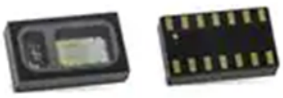
The air pressure sensor can detect fast changes in air pressure which can be this can be a symptom of a fall. A small metal package air pressure sensor with a watertight sealing is used.

Gyroscope



The motion sensor is a 3-axis digital output gyroscope. With the aid of the motion sensor data motion patterns outside the ‘normal’ envelope can be detected which can be a harbinger of a fall.

Heart rate sensor



The integrated heart-rate sensor provides information to monitor the heart rate. The selected component is optimized to detect Heart Rate (HR) and Heart Rate Variability (HRV). For future upgrades of the product also the available Oxygen Saturation (SpO_2) function available in this component could be used.

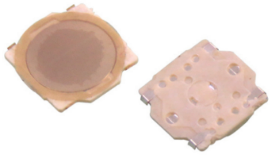
Vibration motor

As an additional alarming and for the elderly with a visual- and / or hearing impairment a DC Vibration motor rotating at 15000 RPM is included in the wearable device.

Buzzer

For the buzzer function a small SMD piezo Buzzer is used. Resonant Frequency: 4000±500Hz square wave.

Push button switch



For the momentary switch function an ultra-thin Film Touch ButtonTact Switch is used.

In the list above, the LED ring that will be used to inform the elderly that an alarm has been set is missing. This LED ring will be placed around the push button and can emit two colors of light. Due to the specific size, it is difficult to find a suitable LED ring on the commercial market. Optionally, it could be an option to order a push button with an LED integrated, but most likely Teneo-IoT B.V. has to order a customized product.

Figure 50: Example of a LED ring with 12 smart LED NeoPixels arranged in a circle (37mm outer diameter). [67]

7.1.2 Detecting of a fall

The automatic fall detection must discriminate falls and other motions like going upstairs, going downstairs, standing up, sitting down and laying down. A built-in triaxial accelerometer, a speed sensor, a heartbeat sensor and an altitude sensor collect data of body motions and heartbeat. Human motion data and heartbeat data collected from these sensors, are stored and used to train a machine learning model. The motions are classified into different patterns, including vertical activity, lying, sitting (or static standing), horizontal activity, and fall. Especially for the elderly the patterns of normal motion will be quite different from a fall as the elderly in the target group will not be very active when they are alone. They will not play sports like tennis and physical exercises are normally done under the supervision of a helper, without wearing the fall detection device. Another method of classification is the decision tree method. For all fast changes of parameters like acceleration, speed, air pressure and heartbeat thresholds are set in an envelope. If one or more of these parameters change faster than the set threshold, the other parameters are analyzed to discriminate a fall.

7.1.3 Battery and wireless charging

This section will further explain the considerations that lead to the final choice of the battery and other issues related to the power management of the product. To minimize the time the wearable device is not worn, it is important that the intervals between charging and the charging time are low. The battery is the most 'volume consuming' part in the wearable device, so the challenge was to find the optimum of a battery that fits without making the device bulky and still stores sufficient energy to guarantee an acceptable interval time between charging and time of charging. The wearable device has a 'battery low' LED, to notify the user the battery has to be charged within 24 hours. The carers in the app will also be notified by the message 'battery low' in the app. The message in the app also shows the remaining time before charging. This will enable them to send a reminder to or help the user with charging (in case the wristband is locked). The carers in the app will also be notified when the device is charging by the message 'charging' in the app.

7.1.4 Materials

The wearable device can be exposed to severe influences like using outdoors and during showering. This application requires a weather-resistant plastic that can withstand the negative impact of ultraviolet radiation, moisture and contact with the human skin. So the device should not discolor and no changes in mechanical properties should appear over time. It also must be resistant to detergents and easy to clean. The wristband material should not be cracking by stress, should not develop brittleness or decrease in strength, elasticity and hardness. The surface should feel nice 'soft and warm', not be sleek and should not irritate the skin. All these requirements must be included in the selection of the material from which the product will be produced.

7.1.5 Attachment and locking

In the ideation phase (chapter 5) several types of wristbands and attachment mechanisms have been explored. As mentioned in the ideation phase, for the final concept was decided on a concept where one side of the wristband slides inside the other part and will automatically be locked. This concept has been further developed in this phase of the project.

Figure 51: Development process attachment and locking

For the strap and clasp concept, research has been conducted into similar closure mechanisms, as shown in figure 51. The parts can be slided into each other until it fits around the wrist. The same principle is used for this as used for a tie wrap. In figure 53 on the bottom view and the side view of the upper part of the wristband the sawtooth shape is shown. In figure 53 the clasp mechanism is shown. By pressing both buttons on both sides, the leaf spring will move down and the clasp is open.

Figure 52: Attachment and lock on wearable device

In some cases, a light coercion may be necessary to promote the use of the product by the elderly. In certain cases it may even be necessary the user cannot take off the device by himself. For example, if the user suffers from dementia or forgets to wear the device due to forgetfulness. For these cases the wristband of the wearable device can be locked in such a way that the user cannot take off the device by himself. To make the unlock a two hand operation (in case of a user lock), there are two clasps on the wristband one for normal opening and one with an additional lock mechanism. The lock mechanism of the wristband is shown in figure 52. If the slider (which is in the inside of the wristband) is in the right hand position, the clasp 1 and 2 can only be opened by pushing both buttons on both locks. If the slider is moved to the left the clasp 2 is open all the time and the wearer can take it off with one hand.

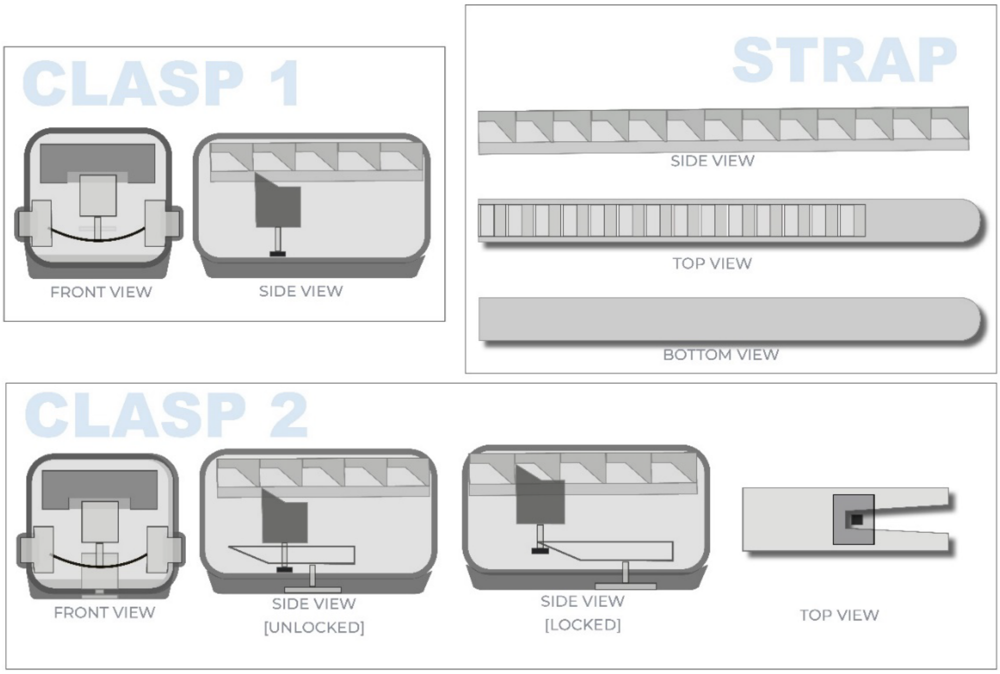


Figure 53: Lock mechanism of the wristband

7.1.6 Dimensions

It is challenging to place all the necessary components in a small casing that fits on the frail older person's wrist. The weight also had to be taken into account, because too much weight negatively affects the wearing comfort.

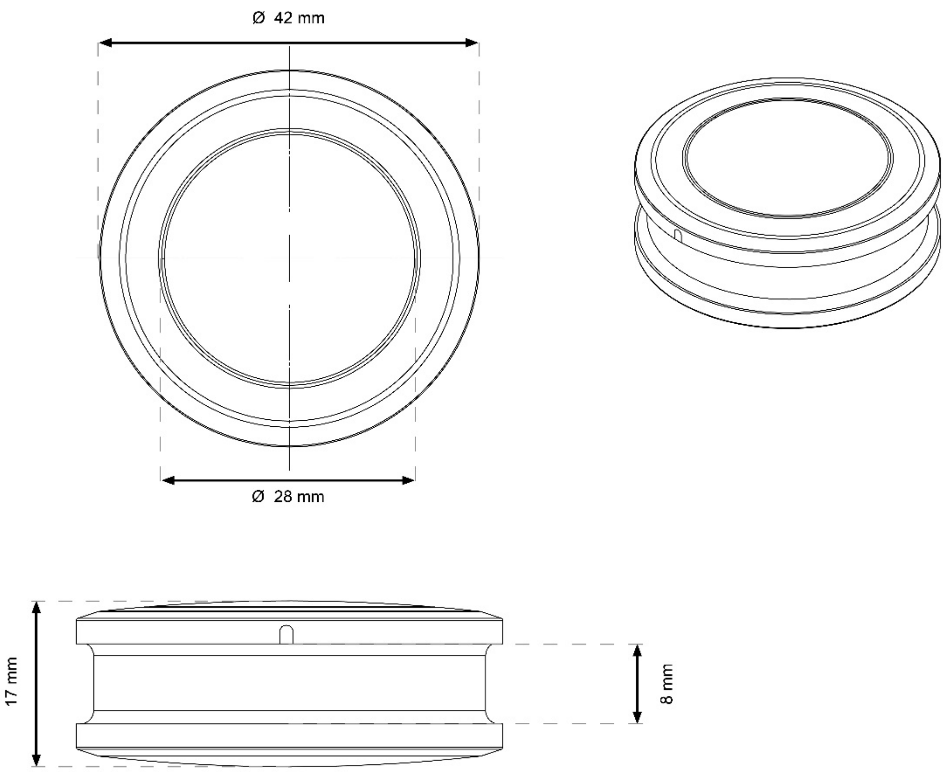


Figure 54: Main dimensions of fall detection module

7.1.7 Technical product model

The overview in Appendix F shows various tools that could be used in this project by a Creative Technologist to realize a prototype. It was decided not to make a physical prototype because testing with the target group would not be possible because of the Covid-19. The emphasis was also on developing innovations for a whole system concept instead of improving only a single small part of the total concept. Therefore it was decided to make a technical model of the complete product. The software used to create this model is SOLIDWORKS. SOLIDWORKS is a Three-Dimensional (3D) Computer-Aided Design (CAD) application. [68] PhotoView 360 is used to create the photo realistic renderings and animations.

To make the product suitable for different applications, a standard casing has been developed in which different components can be placed depending on the application. The casing has a waist around it so it can be pressed easily in different supporting wearing structures.

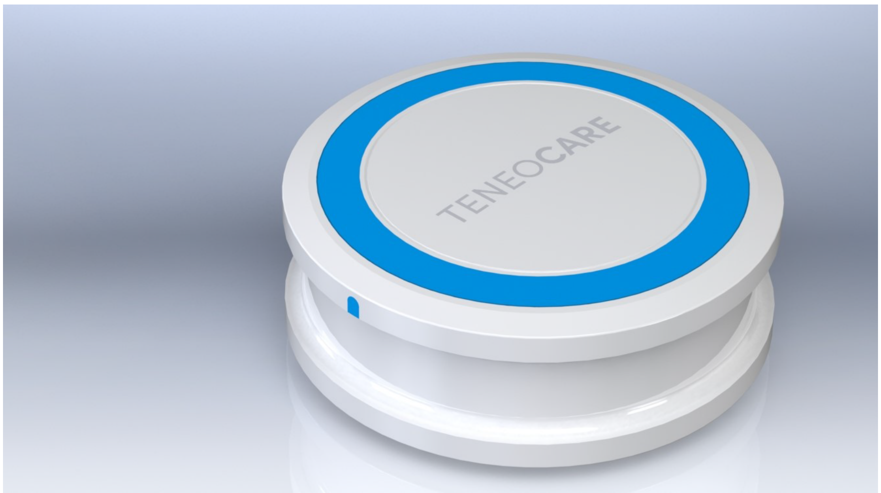


Figure 55: Module casing

The figure below shows the module placed in a wristband.

Figure 56: Module mounted in a supporting wearing structure

In figure 57 the exploded of the fall detection device is shown. A technical package with all necessary sensors and auxiliary parts and their actual sizes was created as a foundation for the final design. To keep the dimensions small, the most efficient way of arranging components was determined. The research for this optimized packaging resulted in a design with four layers on which the components are placed. Some parts had to be placed at a certain place and position because of their function, like the pressure sensor which needs an opening on the side and the heartrate sensor which needs to be placed on the bottom.

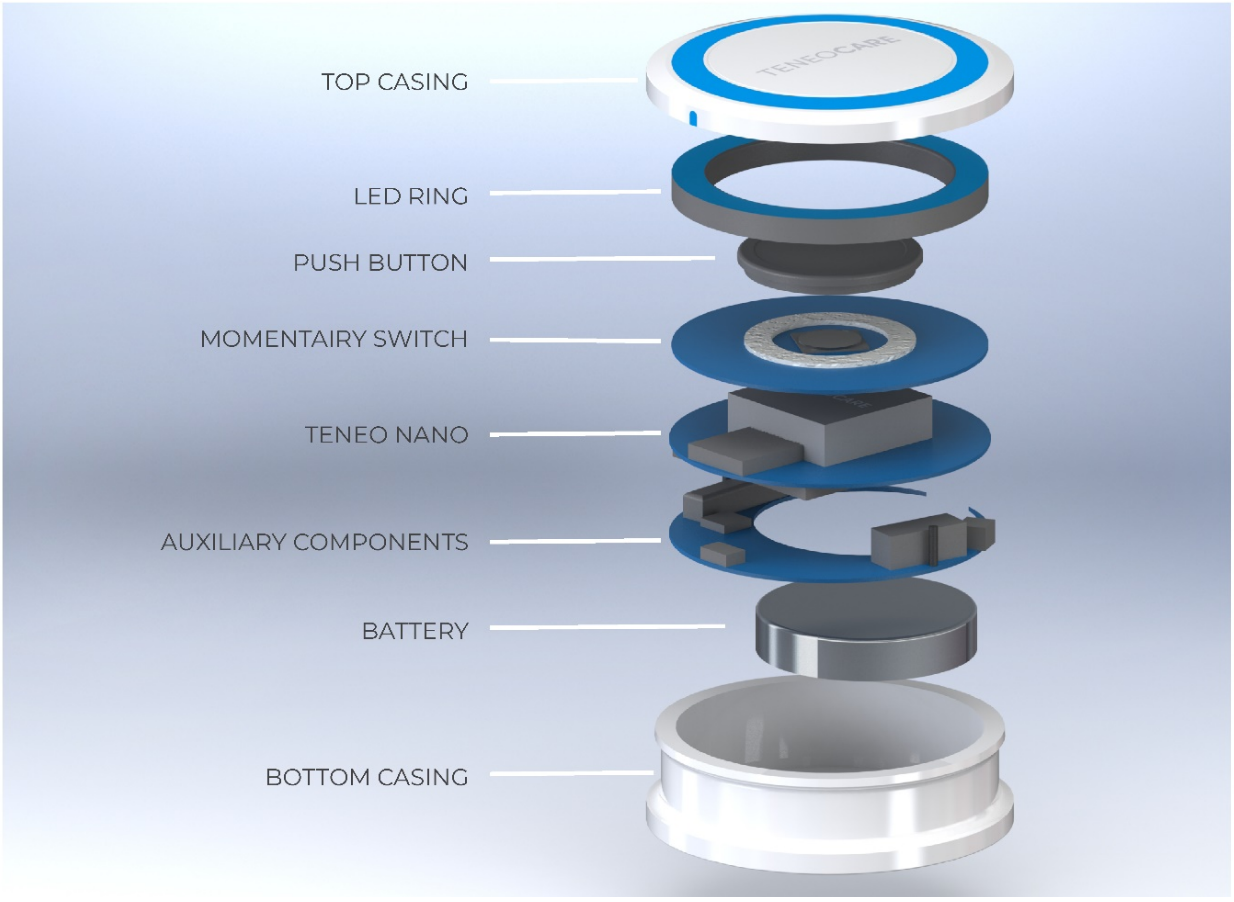


Figure 57: Exploded view of the module

7.2 Smartphone app

After describing the realization of the wearable device, this section will explain in more detail the realization process of the smartphone app. First, the design identity of the smartphone app will be captured in the UI design kit. This design kit will then be used to realize the mockup of the smartphone app.

7.2.1 UI design kit

Before the wireframe design (section 6.1.5) of the smartphone app can be converted into a high-fidelity mock-up design, it is first important to determine the design identity of the product. The design identity of the smartphone app is shown in the UI design kit in figure 60. There are a lot of things to keep in mind when designing a user interface. This kit has been compiled based on the requirements of the stakeholders and UI principles from literature research. Current literature gives a lot of different pointers on what is important; converted in a collection of standards, rules, and guidelines with design recommendations. The main design guidance for the design kit is the guidance from Material Design, a design philosophy from Google. Material Design is a visual language that synthesizes the classic principles of good design with the innovation of technology and science. [69]

Layout

- <u>Hierarchy:</u> *“by placing important actions at the top of the screen they’re given more importance in the hierarchy.”* [69]

This is the reason why it was decided to pin the alarm section, the most important part of the app, to the top of the screen (figure 58). The alarm section at the top of the screen will be visible on every screen within the app.

- <u>Grouping:</u> *“place related items of a similar hierarchy next to each other.”* [69]

This is done by placing the icons from the same category next to each other (figure 58).

- <u>Grid and component density:</u> *“maintain balance between component density and the grid layout. To create scannable groups of content, use a less-dense grid layout in combination with high-density components.”* [69]

A 4-column grid was used. This grid is used on all screens within the app. The final version of the app will use a responsive grid. A responsive layout grid adapts to screen size and orientation, ensuring consistency across layouts.

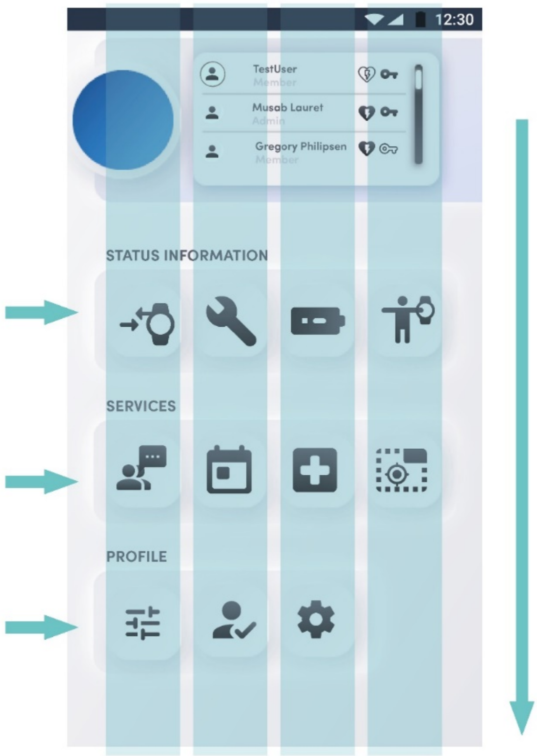


Figure 58: General layout smartphone app. Vertical arrow right = hierarchy, horizontal arrows left = grouping, transparent columns = grid and density

Visual style

Neumorphism was chosen for the visual style of the smartphone app. Neumorphism combines developments of flat design and skeuomorphism. Neumorphism, or soft UI, is a visual style that combines background colors, shapes, gradients, highlights, and shadows to ensure graphic intense buttons and switches. All that allows achieving a soft, extruded plastic look, and almost 3D styling. This way, neumorphic cards, buttons, progress bars have a dark box-shadow below and a light box-shadow above, which creates the look and feel that user interface components are being pushed through a display. [70] This visual style was chosen for the following reasons:

- The "3D styling" makes the user interface components intuitive, because it mimics its real world counterpart (a button really looks like a button that can really be pressed).
- Neumorphism design creates a calm image. Neumorphic UI elements rely on multiple shadows that help blend the element into the background, instead of using bright screamy complementary colors for example.

Color system

Color can help communicate mood, tone, and critical information. Primary, secondary, and accent colors can be selected to support usability. Sufficient color contrast between elements can help users with low vision see and use your app. [69] As mentioned above, Neumorphism design is based on certain color requirements to achieve the "soft UI effect". For a calm and clean look, an off-white background was chosen. The icons and headings are dark gray. This color contrast with the off-white background increases quick and accurate operation of the functions (figure 60).

The various colors one perceives not only have aesthetic value (varying in appeal and preference), but also have communication value, carrying different associations and meanings. [71] This is done by the accent colors, found in the alarm section at the top of the screen. If the app is not in alarm mode, the color of the alarm section is blue. As described in section 5.8, the product must have the look and feel of a modern health care product. Blue (in combination with white) is a color that is often linked to the healthcare sector. This is can be explained logically, because the color blue is typically associated with credibility, trust, knowledge, power, professionalism, cleanliness, calm and focus. [72]

When an alarm comes in and the app goes into alarm mode, the color of the alarm section turns to violet. In daily life, red is commonly used to convey danger or danger-relevant concepts. Red is the prototypic color of alarms, sirens, stop signals and warning signs that convey danger and the need for vigilant attention. [71] However, research on this has shown that the color red in an alarming situation can also cause unnecessary stress and panic. In addition, red is also the color for a "stop signal", while carers must act calmly, appropriately and immediately in the event of an alarm. Therefore, the color violet is chosen. Violet combines the stability of blue and the energy of red. [73]

Iconography

The icons used are shown in figure 60. The smartphone app uses many large associative icons and little text. This is to ensure that the app is clear under all circumstances and therefore the cognitive load is limited. The icons are based on the system icons of Material Design. [69] These system icons are designed to be simple, modern, and friendly. Each icon is reduced to its minimal form, expressing essential characteristics.

Typography

The two fonts used are both clear fonts that are often used in UI application design. [64] Both fonts are modern geometric sans-serif typeface. A sans-serif letterform is one that does not have extending features called "serifs" at the end of strokes. Geometric sans-serif typefaces are based on geometric shapes, like near-perfect circles and squares. This makes the font clear and easy to read on screens.

Branding logo

For the branding logo the design of the fall detection module has been taken as a basis. This is abstracted in the design identity of the smartphone app and Teneo-IoT BV. The round shape symbolizes the group of carers. The style of the logo is modern and minimalist and matches the look of an innovative health care product.

Motion design and interaction states

Motion design informs users by highlighting relationships between elements, action availability, and action outcomes. States are visual representations used to communicate the status of a component or interactive element. States communicate the status of UI elements to the user. Each state should be visually similar and not drastically alter a component, but must have clear affordances that distinguish it from other states and the surrounding layout. [64] In figure 59 some examples of motion design and interaction states are shown.

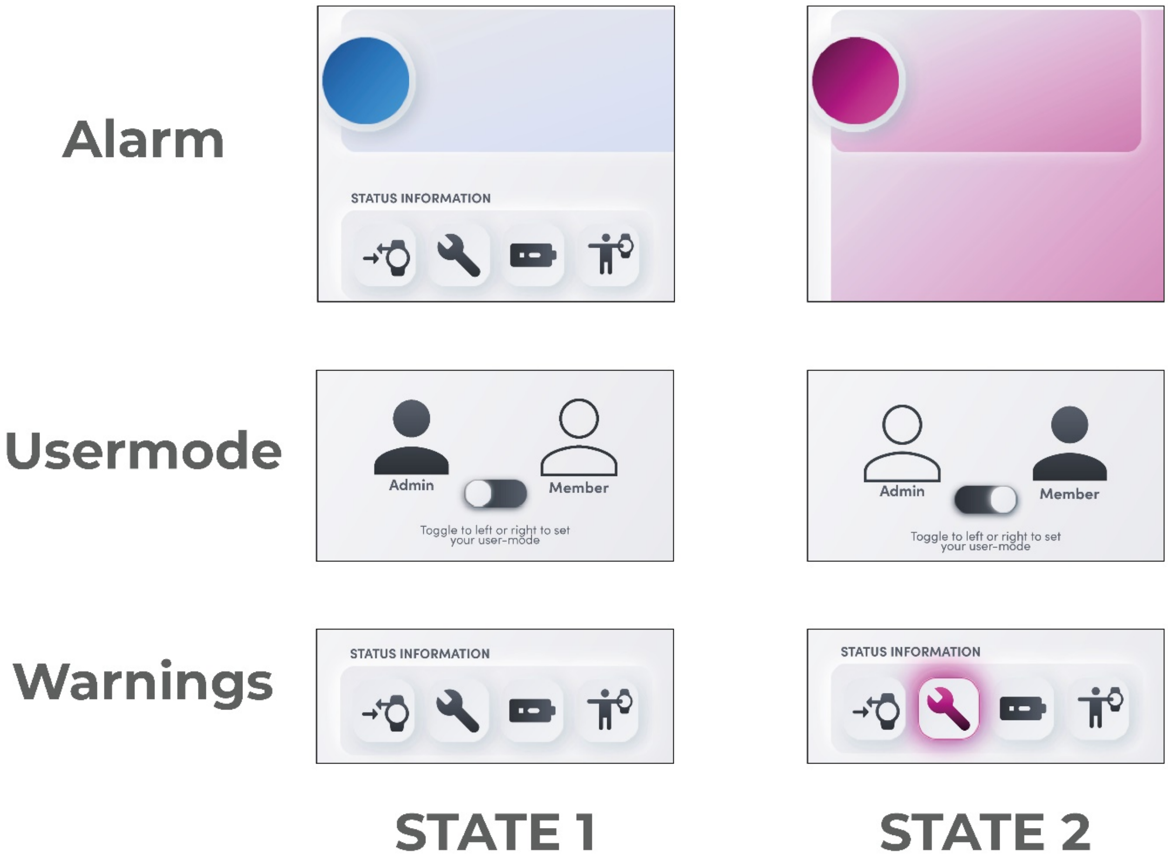


Figure 59: Interactions states

Figure 60: UI design kit

7.2.2 Mockup design

A wide range of tools are available for the realization of a smartphone app. Each have their specific advantages and disadvantages, so it was important to choose the most suitable tool. Adobe XD has been selected to develop an interactive mockup of the smartphone app. Adobe XD is a vector based user experience design tool that is often used to design web and mobile applications. [74] In Adobe XD, it is also possible to create simple animations. This feature has been used to animate the transition from the alarm mode. Animation has also been used for logo. Since Adobe XD is part of the Adobe Creative Cloud, it seamlessly works together with Adobe Illustrator, which will especially be used to create the designs of the icons.

However, Adobe XD also has its disadvantages. Real-time data cannot be implemented, which makes it difficult to test for example the alarm mode properly because an alarm is activated from the wearable device. Moreover, the extension can only be opened in a browser, which may result in different experiences depending on the hardware that the participant is using when doing user testing. Figure 61 shows the most important screens within the smartphone app. All screens can be found in Appendix G.

Figure 61: Mock up design smartphone app. Left to right: welcome screen, login procedure, home dashboard, alarm modus on

7.3 Total product concept

The technical SolidWorks model of the wearable device and the interactive mockup in Adobe XD of the smartphone app have been combined to give an impression to the stakeholders of the total product concept. Figure 62 shows the final render of this concept.

Figure 62: Visualization of total product concept

CH 8_Evaluation

After building the prototypes, the final product concept was evaluated. The evaluation consisted of three parts: (i) requirement verification, to answer the question: 'does the product concept meet all the requirements?', (ii) stakeholder validation, to answer the question: 'does the product concept satisfy the needs and wishes of the key stakeholders?' and lastly (iii) an ethical risk sweeping, to answer the question: 'is the product ethically justified?'.

8.1 Requirement verification

Requirements must be verified to prove that each one satisfies their stated requirement. In this project the verification is done using an interactive mockup of the smartphone app and a Solid Works realization of the wearable device. For some requirements the verification is difficult because obtaining 'hard' evidence is impossible due to the fact the verification is not carried out on the actual realized product. not certain whether all requirements For some requirements the verification is difficult because the verification is not carried out on the actual realized product. For some requirements it is not clear if they are feasible and can be implemented as specified.

Based on the investigation of the end product concept (taking into consideration the issues as described above), can be concluded that the requirements are (partly) met. Clarifications about the results of the verifications are given below.

P	M5	The product MUST have a provision to detect heart rate abnormalities.

This seems to be a good addition to the product which is not implemented in other fall detection systems available on the market, but it needs further investigation. For example:

- What type of heart rate abnormalities can be detected and reported?
- How accurate these heart rate abnormalities can be detected to prevent false alarms or occurrences not been detected?
- Does it need adjustments dedicated to the user?

W	*M13.6*	*The battery of the wearable device MUST guarantee an operation time of 72 hours.*

The selected battery is the best option of the currently commercially available batteries on the market with the highest capacity which fits in the available space. The requirement of an operation time of 72 hours has not been tested but only roughly analyzed. The operation time between charging will highly depend on the processor load which depends on chosen fall detection algorithms.

W	*S6.4*	*The size SHOULD not exceed 40 mm diameter and height 15 mm*

Based on the average size of the wrist of the frail elderly, the size of the wearable device should not exceed a diameter of 40 mm and a height of 15 mm. Due to the large amount of components it was not possible to stay within these limits. Several ways have been investigated to solve this issue:

- *Less functionality:* this would dramatically reduce the unique features of the product.
- *Revised packaging:* several attempts did not lead to any result.
- *Outer edges thinner:* the product would become too weak to withstand mechanical stress.
- *Packaging in thin metal casing:* LoRaWAN- and GPS antenna must be placed outside the casing in the wristband and the modular design would be impossible.

P	*S7*	The selling price of the product including wearable device, wireless charger and *6 accounts for the* smartphone-app SHOULD not exceed *€500.*

The selling price will highly depend on the number of products to be produced and sold. This requires a good market research. The recurring production cost will highly depend on the number of products that will be produced in one batch. The share of development cost recovery in the sales price will also depend on the time and number of products sold in which Teneo IoT B.V. wants to recoup development costs.

P	*C1*	The product COULD be voice controlled.

Voice control for the smartphone app could be a good add on, but it can also be dangerous if in the case of stress situations communication does not go well and misunderstandings arise. Voice control for the wearable device is not necessary because the only control is via the push button.

P	*C2*	The product COULD be able to make an automatic emergency call (112).

Stakeholders stated that automatic emergency calls to 112 are forbidden.

P	C6	The product COULD be able to store monitored data.

This needs further investigation on how this could be implemented. Besides the ethical/privacy issues, there are some technical constraints such as additional processing and memory should be needed. In addition it is also extra load on the LoRaWAN interface and it will have negative impact on the operational time between charging.

P	*C7*	*The product COULD be able to send an alert if the body temperature of the person wearing the wearable device is over 38℃ for more than 3 hours*

This seems to be a nice actual addition on the product, but which needs further investigation. How reliable and accurate is the detection? For instance how to detect if the user is in the sun and the device is heated by the solar radiation?

W	*C8.3*	*The battery COULD be replaceable.*

To replace the battery a provision to open the casing is needed. Given the requirements for water tightness and dimensions, this needs further investigation.

8.2 Stakeholder validation

The stakeholder validation was conducted with three groups of stakeholders: (i) client review (2 participants), with the owners of Teneo-IoT BV, (ii) expert review (6 participants) with the employees of Teneo-IoT BV and lastly (iii) with a group of end users (2 participants) of the product, namely informal caregivers. Due to the current COVID-19 situation, it was not possible to carry out an evaluation with the other group of end users, the elderly. In addition, it would also have been difficult to test the prototype with the elderly, because no physical prototype was made of the wearable device. The number of participants who took part in the evaluation is low, so the target group may be misrepresented so it was only possible to conduct qualitative research. The purpose of this evaluation is therefore not to prove a point empirically but rather evaluate the concept for iterative design, doing the evaluation like this still gives new and valuable insight and understanding of the product concept and its user.

8.2.1 Owners of Teneo-IoT BV (client / expert review)

Two experts, Inou Heidemans and Erik prange, both owner of Teneo-IoT BV, were asked to give feedback during online evaluation sessions. Inou Heidemans is also the external supervisor of this project. Inou Heidemans' expertise is sales, marketing and strategy development and Erik Prange's expertise is technical innovation. Both have individual evaluated the product concept. The main evaluation points are highlighted per product part.

Wearable device

- *Modularity*

Both client experts were positive about the concept of a modular wearable system. It was noted that in addition to this modularity, further personal customization and flexibility can contribute to the acceptance of the product by the elderly. A disadvantage of the modularity is that, for example, heart rate and temperature only work if a wearable device is used as a wristband.

- *Technical feasibility*

Both experts were critical about the technical feasibility of the system. First of all, they noticed the size of the module seemed to be too small to fit all components in. Especially because the battery and GPS are large components. The Teneo Nano will actually be bigger than the exploded view shows, but still has to be explored to what extent this can be miniaturized. For the design the ultimate dimensions were not available because the Teneo Nano is characterized as a 'built on' chip.

There were also questions about detecting a fall accurately from the position of the wrist. One of the experts stated that it will be difficult to detect a fall this way because it is not a fixed point as for example the hip

A further drawback is that no accurate power consumption calculations have been made for the battery. The experts expect a battery with more volume will be required to realise the time between charging.

Technical feasibility modularity also an issue: different software for each wearing method is complex. The best ways of detecting a fall have yet to be properly investigated.

Smartphone app

- *Usability test*

Both experts had few problems with completing the tasks. In most cases they reached the screens corresponding to the task within a minimum amount of clicks. Their comments during executing the tasks also showed that they understood the functionality of the parts during the usability test.
During the usability test, different issues were noted by both experts:

- At the 'User Mode' screen, it is more intuitive to click on the person icons than to toggle the toggle switch underneath.
- Send verification code via SMS instead of email, because it is a smartphone app.
- Both experts found the possibility to see whether a carer has access to AED and elderly's' home an important addition to the carers list. Though, it was suggested to change the 'key' icon to an icon of a 'house'. In addition, it was mentioned that numbering 'carers list' would more clearly indicate the ranking of the list.

Several points for improvement were also mentioned during the testing of the alarm mode. Erik Prange mentioned, for example, that if in an emergency situation he indicates that he is available to provide assistance (top carer in the carers list), he would like to have the possibility to tick two people in the carers list to remain on standby.

- *UI design*

Both experts mentioned that they liked the use of many big icons which contribute to the ease of use of the app. They rated the icons as straight forward. Both experts were also asked whether the look and feel matches the branding of Teneo-IoT BV. They mentioned that the minimalist design matches the professional look that Teneo-IoT wants to emit.

Erik Prange mentioned as a recommendation to think about ways in which functions could be merged or perhaps omitted, to limit the amount of information and possible functions on the home dashboard to reduce the complexity of the app. This is in line with the vision of Teneo-IoT BV to strive to make products as simple and stripped down as possible.

Product

- *Ethical issues*

Including the medical profile in the app was addressed as an ethically difficult issue. There are strict standards for the medical certification of apps. For Teneo-IoT BV there are also risks as a company, such as: who is liable if the alarm does not go off in an alarm situation? The product is a consumer oriented product which entails additional issues of this kind for the supplier, while Teneo-IoT usually trades on a business to business basis.

- *Price evaluation*

Inou Heidemans estimates the price people are willing to pay for the product: €200,-. Erik Prange estimates a maximum price of: €500,-. It seems there is a gap between the costs of the product and the price people are willing to pay for it. But in general people are willing to pay a lot for "buying a feeling of security", see for example the price of an AED.

- *Different operating situations*

Erik Prange commented that the product should be useable in different operating situations with for instance 10 wearables in different groups and one administrator. Or a family in which the elderly father and mother both use a wearable device but with the same group of carers. Besides the fact that organizing care groups in care homes is difficult, care homes often use their own system and they usually do not embrace smartphone apps.

8.2.2 Employees of Teneo-IoT BV (expert review)

The expert review by the employees of Teneo-IoT BV was conducted in the form of an online questionnaire evaluation (see section 4.5.1 for more information about method). The demographic questions revealed that all participants were aged between 18 - 35 years. It can be difficult for these persons to empathize with the situation of the frail elderly, but their contemporary view of the problem and their knowledge of the technical possibilities, can also yield new original ideas. Also can be noticed that the group of participants consisted of an account manager, a graduate in commercial economics and four software engineers. This diversity could provide critical and diverse feedback on various aspects. The most relevant results are discussed below.

Wearable device

- *Technical feasibility*

The technical feasibility of the modular design of the wearable device was rated on average with 5.1 out of 6. Important remarks pronounced by the technicians were that many tests will be required in order to check if the device works accurately.

Smartphone app

- *Usability testing*

The specific tasks during usability testing were generally well understood and performed. It was striking that the tasks related to the 'carers list' were less well executed. It is not clear to 4 of the 6 participants who has access to an AED and access to the older person's home based on the used icons. In addition, half of the participants did not know how to see in the 'carers list' whether users are available. Important remarks after independently testing the app were:

- Placement of a label with title of function below the icons.
- Develop a 'Home Dashboard' icon to return from other screens to the 'Home Dashboard . The arrow currently used as icon suggest going back to previous action instead of going to 'Home Dashboard'.
- In the 'carers list' indicate icons of access to AED and home in different colors when someone has access or not (e.g. blue and purple), instead of color-filled icon when access and outlined icon when no access.

- *UI design*

The app's UI design was tested using a series of ratings questions. The use of colors and color scheme within the smartphone app were generally rated as positive. The majority also felt that the use of colors matches the branding of Teneo-IoT. One participant's feedback was that using more associative colors would make the app less complex. It was also mentioned that sometimes too much information was shown seen on one screen. A participant posted the comment that some text should be bigger. The font used was also positively assessed. The average score on the statement: 'I miss an onboarding / introducing tour / built-in manual' was 4.5 out of 6. This implies that additional explanation is needed to understand the app, for example some explanation of the icons and the alarm section.

Total product

- *Acceptability*

4 out of 6 participants do not expect the elderly to feel stigmatized by using this product. The main arguments for this were that the modular construction means that the elderly can also wear the product (almost) invisible. The product has the look and feel of a modern safety accessory, so does not have to be stigmatizing. It was mentioned that the main reason why it could be stigmatizing is because of the size of the module.

- *Privacy and personal contact*

In general, the participants think that personal contact between carers and elderly, but also between the carers themselves, is positively influenced by the product. The product gives older people more freedom and carers have less worries because they can see more easily whether older people need help. It was indicated that obsessive monitoring and privacy violations can largely be prevented by only revealing the location and medical profile of the older person in the event of an emergency situation.

- *Price evaluation*

5 out of 6 participants would willing to pay an amount between € 200 - € 300 for this product. A participant would like to pay € 300 - € 400. This is probably estimated too low because no account has been taken of the earning back of the development costs.

- *Key values*

Finally, the participants were asked to describe their first thoughts that come up when thinking about the product. This could be described as what participants think they feel is the key value of the product. This information can be insightful for marketing purposes. The descriptions given by the 6 participants:

1. *“An app and wristband that allows you to monitor an elderly person and offer quick help if something is wrong.”*
2. *"Extra safety for the elderly."*
3. *"An easy to use system with more functions than a traditional emergency button."*
4. *“A smart app with wristband alarm button.”*
5. *"Emergency system."*
6. *"A product that detects a fall of one of your parents or grandparents and offers help of people nearby by using an app."*

When asked what they think is the best aspect of the product, the answer was: the amount of functionality, user-friendliness, the alarm function (2x) and location determination of an elderly person in need.

8.2.3 Informal caregivers (end user review)

Finally, two individual evaluation sessions were conducted with informal caregivers. These sessions were less extensive than with the owners and employees of Teneo-IoT, because technical aspects could be disregarded. The most interesting points of attention mentioned by the informal caregivers were:

- The integration of a clock in the button of the wearable device, so the older person does not have to wear two wristbands.
- Expand the use of the temperature sensor in the wearable device to detect conditions, for example COVID-19.
- To show less information on the Home Dashboard of the smartphone app and merge information where possible.
- To make the smartphone app suitable for a tablet.
- Also use the location of the carers for priorization of the carers list. Carers which are far away from the person in need of help could be disregarded in case of an emergency.

8.3 Ethical risk sweeping

A product or service must be ethically justified before it is launched on the market. For implementing the ethical needs of all stakeholders in this graduation project in a correct and structured way 'The ethical toolkit for engineering/design practice' was used. [75] An ethical risk-sweeping is done to detect missed and new ethical risks. Ethical Risk Sweeping means a broad and shallow search for ethical risks during the development of a new product. Ethical Risk Sweeping must be performed during all phases of the development.

In certain cases it may be necessary the elderly cannot take off the device by himself. By using the system, elderly will also lose some of their privacy and can feel to be spied on. The geo-fencing severely limits the freedom of movement, but on the other hand it can provide freedom of movement to those who would otherwise never be able to go out alone. All of these items relate to the 'Golden rule': don't put others in a situation you won't be in yourself. The Golden Rule is a universal rule, the principle of treating others as you want to be treated. [76]

'Don't put others in a situation you won't be in yourself' means of course 'yourself placed in the position of the other person'. For a young creative technology student it is hard to imagine being a frail elderly, so it is very important to consult the stakeholders in this case the frail elderly themselves and also geriatric specialists. There are many pitfalls: Have the right questions been asked in the interviews and survey? Were the questions not suggestive? Isn't the direction I had in mind leading in the design? Did I understand what the older person really means?

Ethical Risk Sweeping on the design of the product resulted in 12 individual ethical risks for Teneo Care the caregivers and the caretakers. Table 8 lists the ethical risks found in this project. For each risk several ways have been considered to avoid or mitigates the risk or to avoid the consequences in case a risk would become true in the future.

Table 8: ethical risks and mitigation / avoidance

	Ethical risk	Mitigation/Avoidance
1	The innovative fall detection system will include a built-in GPS system to determine the location of the elderly. The location of the wearable device is visible in the smartphone-app. The elderly will lose some of their privacy and can feel to be spied on. Obsessive monitoring by the caregiver can lead to obsessive-compulsive disorder.	The location information is only visible on the app in case of an emergency. The data is stored securely and encrypted and is in case of no emergency only available after entering a pin code or a fingerprint scan.
2	The product has a provision to detect heart rate abnormalities and falls. People are going to trust this	A visit schedule is added in the app.

	app and personal contact may become less, which can result in loneliness of the elderly.	
3	The product can be stigmatising because it shows that someone is in need of help. Some elderly described wearing a personal alarm button as necklace as like wearing a "badge of dishonor". This fear of stigmatization can be very powerful, and can result in a refusal to wear it.	As wearable device is chosen for a wristband and not for a necklace with a large red button. The device is unobtrusive but recognizable as an emergency system.
4	When the caregiver thinks he/she always has to be available for the person in need, this can result in compulsive behaviour and can have a major impact on their private life.	The smartphone-app users (caregivers) can set their availability in the app. If there is no response within certain time of the smartphone-app user who is alerted in case of an emergency, the next person in the predefined list of carers will be alarmed.
5	The administrator of the app is able to add or delete persons from the list of carers and can change the priority of the list. This can lead to disagreement in the group of carers.	The care taker has to approve the list and the priority on the list.
6	The wristband of the wearable device can be locked, so the user cannot take off the device by himself. This may restrict the free will of the care taker.	In some cases, a light coercion may be necessary to promote the use of the product by the elderly. In certain cases it may be necessary the user cannot take off the device by himself. For example, if the user suffers from dementia or forgets to wear the device due to forgetfulness. In the latter case there should be a written statement of a professional carer stating that the use of the device is in the best interest of the patient. The wearing comfort will be excellent and the risk of injuries from wearing the device will be minimalised.
7	The product must be affordable for all people who needs this kind of device.	The selling price will be less than €500. There will be no additional costs for a subscription and updates.
8	The smartphone app will provide information on how to enter the house of the user of the wearable device. This information can be stolen by hackers and used for burglary.	This information is only added with the permission of the care taker and will only be displayed in the app in case of an emergency. The data is stored securely and encrypted and is only available after entering a pin code or a fingerprint scan.
9	The smartphone-app includes a medical profile of wearable device user for health professionals (ambulance personnel and doctors). This information can be stolen by hackers and used for burglary (blind elderly) or sold to fi. Insurance companies.	This information is only added with the permission of the care taker and will only be displayed in the app in case of an emergency. The data is stored securely and encrypted and is only available after entering a pin code or a fingerprint scan.

10	The smartphone-app has integrated geo-fencing functionality. An alert is send to the caregiver when the wearable device user is outside the 'electronic fence'. This functionality severely limits freedom of movement, but on the other hand it can provide freedom of movement to those who would otherwise never be able to go out alone.	Geo-fencing functionality can only be set by the administrator and after approval of the elder person. Geo-fencing data is only available on the app after an alert. The data is stored securely and encrypted and is only available after entering a pin code or a fingerprint scan.
11	The product is able to store monitored data. The logged data can be used for product improvements, fall-prevention and for (medical) research. This is private data that belongs to the care taker. The caretaker may not want the carers to know how often he/she almost has fallen, for the carers could because of that impose more restrictions.	This information is only added with the permission of the care taker. Data - and privacy protection has to be implemented.

Some risks are critical ethical risks which are complex to mitigate or to avoid can lead to major tragedies:

- The wearable device has a provision to detect heart rate abnormalities. Medical staff and carers will rely on this system, but what if the person wearing the device dies and the system did not automatically generate an alarm?
- The system also has integrated geo-fencing functionality, that will send an alarm to the care giver in case the elderly is trespassing the border of the geo fence. But what if the person wearing the device is run over by a car outside the geofence and no alarm was sent the moment the person wend outside the geo fence?

To avoid or mitigate these critical risks extra attention in the design should be given to these aspects. Teneo-IoT B.V. must carefully investigate these kind of risks and to what extent they can be held liable in the event this kind of risks become true.

CH 9_Conclusion and discussion

This final chapter will start by providing a comprehensive conclusion in which the main findings of this graduation project are summarized. Thereafter, the most important limitations and recommendations are discussed.

9.1 Conclusion

This graduation project presents the research and conceptual design of a new fall-detection product for older adults (70+) and their carers. The goal was further development of Teneo Care: a product which makes it possible for elderly or disabled persons to be more independent and give people a more safe feeling by providing an active fall-detection product, which alarms family or caregivers when someone has fallen.

The Cycle of Falling, the vicious circle that arises after a first fall, showed that there are many more elements involved around a fall than just the fall incident itself. In order to minimize the decline in physical and mental health due to falling, it is important to investigate how to influence this cycle. Which aspects should be changed and which technologies and methods can best be used for this. The two main methods to influence the circle are fall prevention and fall detection.

A literature and state-of-the-art research was conducted for both fall prevention and fall detection methods to gain insight into the main principles of both methods and the strengths and weaknesses of the systems currently available in market. After a number of iterations and both weighing fall detection and fall prevention and what is possible within the COVID-19 situation, the following research question was formulated:

> *"How to develop a fall-detection system for elderly that fits within the vision of Teneo Care and by focusing on a need-driven instead of technology-driven approach?"*

To answer this research question, first the exact needs and wishes of the stakeholders are captured by means of a stakeholder analysis. These needs and wishes are elaborated during a brainstorming session to implement as many of those needs in one product as possible. The brainstorming gave several solutions, but also a new ideas. These results were captured in a set of preliminary requirements. These requirements have been used to explore different concepts for a fall detection system.

The final product concept consists of a modular wearable device for the elderly and a corresponding smartphone app for a group of carers, for example partner, family, informal caregiver and neighbours. The wearable device can send an alarm to the carers in the smartphone app in the following three situations: first (i) an automatic fall alarm, in case a fall has been detected, second (ii) a personal alarm, in case the older person needs help he can send an alarm by pressing the alarm button by himself, and third (iii) an emergency push alarm, which is automatically send in case heart rate abnormalities or no heart rate has been detected. In the event of such an alarm, the carers are warned by the smartphone app going into alarm mode. A list in which the group of carers are ranked determines who should be automatically asked first to provide immediate assistance.

This final concept has led to the design of 2 prototypes that have been used for evaluating the project. For the wearable device a technical product model has been made with the tool SOLIDWORKS and for the smartphone app an interactive mockup was realized with the tool Adobe XD.

The evaluation of the final product concept was done using the following three methods: requirement verification, stakeholder validation and an ethical risk sweeping. The requirements verification showed that it is difficult to determine whether some requirements have been met, because they are difficult to test because no physical prototype has been built.

The stakeholder validation showed that the product concept satisfied the needs and wishes of the stakeholders. The main feedback and recommendation related to the technical feasibility van product and the amount of available information on ‘Home Dashboard’. The ethical risk sweeping indicated that before the product is launched on market it is important to identify and mitigate all possible ethical risks.

Ultimately can be concluded that the research question has been partially answered. During all phases of the project, the focus has been on the needs and wishes of the key stakeholders. This has led to a top down development process in which all associated aspects have been taken into account from the start (no exclusion, broad view) and this resulted in an innovative conceptual design for Teneo Care, which is much more than just a fall-detection sensor. However, because the final design is only a conceptual design, it was not possible to fully test the technical feasibility.

9.2 Discussion

This section describes the limitations encountered in this project and the recommendations for future work are suggested.

9.2.1 Limitations

In general face-to-face contact was difficult as a result of the COVID-19 pandemic. Direct face-to-face contact with the target group (frail elderly) was not possible, and digital contact with the elderly was also difficult because most of them are not familiar with modern digital means of communication. As a result, testing with a physical prototype was not possible. Problems would also arise when building a physical prototype because of the disrupted parts supply due to the COVID-19 pandemic. Neither was research allowed in care homes and it was not allowed to contact healthcare professionals. As a result, the focus has only been on elderly people living at home and informal caregivers.

Several iterations have been done in the ideation and realisation phase. The last iteration after the enquetes and surveys still has to be carried out based on the analysed results of the enquetes and surveys.

9.2.2 Recommendation for future work

Some important recommendations for future work are given by stakeholders in the feedback during the evaluation of this project. The deliverable in this project is only a prototype of the product. It still needs several steps to full realization of a producible and sellable product.
The conceptual development of this product is a first step to set up a new product line within Teneo-IoT: Teneo-Care. This conceptual development can be used to detail a technical roadmap for this product line. It gives ideas to penetrate this market with an innovative not stigmatizing product with sophisticated features that not yet exist on similar products currently available on the market.
Teneo-IoT should first concentrate on the wristband version of the product and when this product is on the market then gradually expand the catalogue with different wearing methods (wristband, belt, neckless) and modules for other functions (health tracking, sleep monitoring, fitness etc.).

One of the first steps is to select and implement an algorithm that needs a low processing power, has a high fall detection probability and a low false alarm rate. This algorithm has to be adapted in the future to make it suitable for fall detection for the different wearing methods (wristband, belt, neckless). It is recommended to use the huge existing expertise on fall detection algorithms and to have these algorithms adapted for this specific application by external experts in this field. Developing and duplicating this knowledge from scratch onwards within Teneo-Care would not be cost effective.

More accurate calculations on battery power consumption should also be done to gain a better insight in the time between charging and the duration time of charging. Another way of charging the wearable device could be considered: to charge while the wearable device is still worn on the wrist: by putting the wireless charger on or around the wearable device, may be with an integrated powerbank.

Based on the mockup, the app has to be developed. Some remarks on the app to consider:

- The icons must light up if there is a status change.
- Ensure that the carer who provides assistance can also ask others to assist.
- Implement the onboarding or user guide.

High-fidelity prototype testing with the entire target group should be done for a more in-depth UX / UI evaluation and a more realistic usage environment, this was not yet possible due to COVID-19. It is important to find out whether the elderly and the caregiver can use the product in the correct way and the elderly do not feel stigmatized.

Investigate how this product can be used in other market segments and other target groups like nursing homes, physio, hospitals. For some of these users it may be necessary to connect multiple wearable devices on one app.

Further investigation on ethical dilemmas is needed. An initial study on ethical risks (section 8.3) has been carried out, but due to the fact that people depend and rely on this product and the high liability risks of this product for Teneo IoT B.V., this needs to be further investigated to mitigate or eliminate these risks.

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Appendix

Appendix A Interviews [Ideation]

Interview procedure - Teneo-IoT *Inou Heidemans*

<table>
<tr><th>Nr.</th><th>Topic</th><th>Questions</th><th>Response + notes</th></tr>
<tr><td>1</td><td>Teneo Care</td><td>Possible Questions
- Wat is de algemene visie / missie van Teneo Care?
- Wat zijn belangrijke aspecten bij valdetectie product?
  - Waterdicht?
  - Vallen uit bed / voor de nacht?
  - Batterijduur Indicatie?
  - Hoe opladen?
  - Interface met gebruiker? (spraak, touch, etc.)
  - Design? (type wearable, materiaal, etc.)
  - Gebruikerstaal?
  - Duurzaamheid?
- Welke extra services bij valdetectie product?
  - Coaching bij valpreventie oefeningen?
  - Alert medicijngebruik?
  - GPS?
  - Routebegeleiding naar woonlocatie?
  - Instabiliteit monitoring (en melding)?
  - Sociale contacten?
- Wat zijn de unique selling points?
- Waar valdetectie product (wearable) dragen op lichaam?</td><td></td></tr>
<tr><td>2</td><td>Economische aspecten / marketing plan</td><td>Possible Questions
- Hoeveel producten verkopen op jaarbasis?
- Wat worden de afzetkanalen / klanten?
- Wat is de maximale prijs per product?
- Wat is het ontwikkelingsbudget?
- Hoe wordt het product in de markt gezet?</td><td></td></tr>
<tr><td>3</td><td>Data en privacy</td><td>Possible Questions
- Welke data wordt verzameld en wie heeft toegang tot deze data?
- Welk netwerk moet gebruikt worden?
- Met wie moet de gebruiker van het product kunnen communiceren?
- Hoe moet het product kunnen communiceren? (dialoog functie?)
- Mag data opgeslagen worden voor analyse?
- Waar wordt deze data opgeslagen?
- Wie heeft toegang tot deze data?
- Moeten ouderen toestemming geven voordat een alert wordt verzonden? (alert na geen reactie na bepaalde tijd)</td><td></td></tr>
<tr><td>4</td><td>Eindgebruikers</td><td>Possible Questions
- Wie zijn de gebruikers? (ouderen, mantelzorgers, partner etc.)
- Voor welke onderliggende (chronische)</td><td></td></tr>
</table>

		aandoeningen moet het product aanpassingen hebben? (dementie, slechtziendheid, slechthorendheid, etc.)
		- Waar moet het toepasbaar zijn?
		  - Binnenshuis / buitenshuis? (aantal km van woonlocatie?)
		  - Woonvorm?
		  - Woonsituatie?	

Interview procedure - Older adult

70+, living independently

Nr.	Topic	Questions	Response
1	Algemene informatie	Possible Questions - Wat is uw leeftijd? - Heeft u zorgverlener(s)? - Hoe communiceert u met uw hulpverlener(s)? - Wat zijn momenteel uw belangrijkste bezigheden?	
2	Woonsituatie	Possible Questions - Omschrijving van woonsituatie (woonvorm, met wie, speciale aanpassingen in woning etc.)	
3	Gezondheid	Possible Questions - Lichamelijke gezondheid? - Chronische aandoeningen? - Doet of gebruikt u op dit moment een product of service om de kans op vallen te verkleinen of de gevolgen van een val te beperken? (noodknop, rollator, etc.) - Ervaart u wel eens een gevoel van eenzaamheid?	
4	Valongelukken	Possible Questions - Hoe vaak bent u gevallen in de afgelopen 5 jaar? - Heeft u angst om te vallen? - Wanneer was de laatste keer dat u gevallen bent? - Bent u wel eens na een val in het ziekenhuis opgenomen geweest? - Was de val veroorzaakt door een intrinsieke factoren (medicijngebruik, slecht zicht, beroerte, lichamelijke beperkingen, etc.) of extrinsieke factoren (struikelen over een stoeptegel, gladde vloer, losliggende mat, opstappen fiets etc.) - Was de val binnenshuis of buitenshuis? - Had u directe hulp nodig na de val? - Hoelang duurde het voordat er hulp ter plaatse was? - Is door de val uw lichamelijke gezondheid verslechterd? - Is u angst voor vallen toegenomen na de	

		laatste val?	

4	Valdetectie	Possible Questions
		- Soort wearable?
		- Welke aspecten belangrijk?
		    - Batterijduur Indicatie?
		    - Hoe opladen?
		    - Interface met gebruiker? (spraak, touch, etc.)
		    - Design? (type wearable, materiaal, etc.)
		- Alarmering?
		    - Wie?
		    - Wie als eerst?
		    - Automatisch / na toestemming?
		    - Hoe te zien aan product?
		- Services?
		    - Coaching bij valpreventie oefeningen?
		    - Alert medicijngebruik?
		    - GPS?
		    - Routebegeleiding?
		    - Instabiliteits monitoring (en melding)?
		    - Sociale contacten?
		- Kosten? Bereidheid tot investeren?
		- Wat maakt product betrouwbaar?
		- Kunt u zich voorstellen zo'n product in de toekomst te gaan gebruiken (als nu niet nodig is)?	

4	Technologie	Possible Questions - Heeft u een smartphone? - Maakt u gebruik van Apps op uw smartphone? Welke? - Welke andere nieuwe technologieën? - Houding ten aanzien van moderne technologie? Neem kwaliteit van leven erdoor toe? - Bereidheid om leren om te gaan met nieuwe technologieën? - Vaardigheden technologie? - Interesse technologie?	

Interview procedure - Informal caregiver

Nr.	Topic	Questions	Response
1	Algemene informatie	Possible Questions - Hoeveel tijd bent u wekelijks kwijt aan mantelzorgtaken? - Hoe communiceert u met degene die u verzorgt?	
3	Gezondheid oudere	Possible Questions - Hoe zou u de lichamelijke / geestelijke gezondheid beoordelen van degene waarvoor u mantelzorger bent? - Is degene waarvoor u mantelzorger bent altijd open en eerlijk over de geestelijke en	

		lichamelijke gezondheid? - Waarom?	
4	Valongelukken	Possible Questions - Bent u bezorgd over een mogelijk valongeluk bij degene die u verzorgt? - Waarom / waardoor bent u bezorgd?	

4	Valdetectie	Possible Questions
		- Soort wearable?
		- Welke aspecten belangrijk?
		  - Batterijduur Indicatie?
		  - Hoe opladen?
		  - Interface met gebruiker? (spraak, touch, etc.)
		  - Design? (type wearable, materiaal, etc.)
		- Alarmering?
		  - Wie?
		  - Wie als eerst?
		  - Automatisch / na toestemming?
		  - Hoe te zien aan product?
		- Services?
		  - Coaching bij valpreventie oefeningen?
		  - Alert medicijngebruik?
		  - GPS?
		  - Routebegeleiding?
		  - Instabiliteits monitoring (en melding)?
		- Redelijke prijs voor product?
		- Wat maakt het product betrouwbaar?
		- Wilt u via bijvoorbeeld een app gekoppeld zijn aan het valdetectie product?
		  - Chatfunctie met meerdere hulpverleners opgenomen worden? (familie, verzorgers, partner)
		  - Hoe staat u er tegenover als u bijvoorbeeld 24 uur per dan een melding zou kunnen verwachten?	

4	Technologie	Possible Questions
		- Heeft u een smartphone?
		  - Welke apps?
		  - Smartphone vaardig?
		- Maakt degene waarvoor u mantelzorger bent gebruik van een smartphone?
		  - Andere nieuwe technologie?
		- In welke mate en hoe snel begrijpt oudere nieuwe technologie?
		- Houding oudere ten aanzien van technologie?	

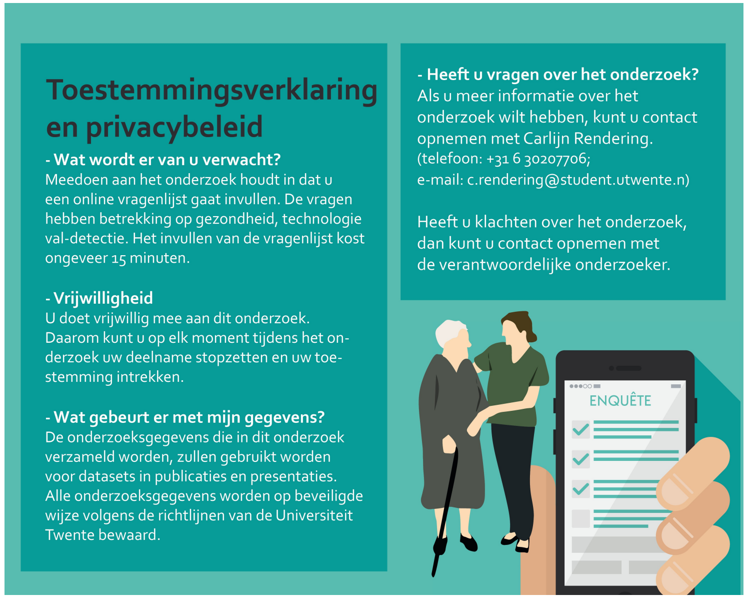
Appendix B Online questionnaire survey [Ideation]

Enquête "Draadloze val-gerelateerde technologieën voor ouderen (70+)"

U wordt uitgenodigd om mee te doen aan een bachelor afstudeeronderzoek naar 'val-gerelateerde technologieën voor ouderen (70+)'. Dit onderzoek wordt uitgevoerd in opdracht van Teneo-IoT (https://teneo-iot.nl/) door Carlijn Rendering, student aan de Universiteit Twente.

Deze enquête is bestemd voor:
- Ouderen (60+)
- Mantelzorgers (vrijwilligers)

*Vereist



1. Door te klikken op de knop 'Ik ga akkoord' geeft u aan dat u de bovenstaande informatie heeft gelezen, vrijwillig meedoet aan het onderzoek en 16 jaar of ouder bent. *

Markeer slechts één ovaal.

- Ik ga akkoord *Ga naar vraag 2*
- Ik ga niet akkoord *Ga naar sectie 3 (Einde enquête)*

Einde enquête

U heeft de enquête verlaten. Hartelijk dank voor uw tijd.

Introductievraag

Om gedurende deze enquête enkel vragen te stellen die voor u van toepassing zijn, zal u eerst op basis van onderstaande vraag gecategoriseerd worden.

2. Tot welke doelgroep behoort u? *

Markeer slechts één ovaal.

- Ouderen (60+) *Ga naar vraag 3*
- Mantelzorgers (vrijwilligers) *Ga naar vraag 12*
- Overig *Ga naar sectie 3 (Einde enquête)*

Algemene vragen

Algemene vragen voor doelgroep ouderen (60+)

3. In welke leeftijdsgroep valt u? *

Markeer slechts één ovaal.

- 60 – 65 jaar
- 65 – 70 jaar
- 70 – 75 jaar
- 75 – 80 jaar
- 80 – 85 jaar
- 85 of ouder

4. Welke term beschrijft uw woonsituatie het beste? *

Markeer slechts één ovaal.

- Verzorgingshuis
- Zelfstandig
- Bij familie in huis
- Serviceflat
- Aanleunwoningen
- Levensloopbestendige woningen
- Anders: ____________

5. Woont u alleen? *

Markeer slechts één ovaal.

- Ja
- Nee, met partner
- Nee, met familie
- Anders: ____________

6. Hoe zou u uw lichamelijke gezondheid beoordelen? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Zeer slechte lichamelijke gezondheid	○	○	○	○	○	○	Zeer goede lichamelijke gezondheid

7. Ervaart u wel eens een gevoel van eenzaamheid? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Ik voel mij zelden eenzaam	○	○	○	○	○	○	Ik voel mij zeer vaak eenzaam

8. Als u buitenshuis bent, vindt u het dan belangrijk dat anderen weten waar u zich bevindt? *

Markeer slechts één ovaal.

- Ja
- Nee

9. Wie mag weten waar u zich bevindt?

Deze vraag hoeft u alleen in te vullen als het antwoord op de vorige vraag 'Ja' was. Als het antwoord 'Nee' was, mag u deze vraag overslaan.

Markeer slechts één ovaal.

- Partner
- Familie
- Mantelzorger
- Hulpcentrale
- Anders: ____________

10. Voelt u zich veilig als u alleen buitenshuis bent? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Ik voel mij zelden veilig	○	○	○	○	○	○	Ik voel mij vaak veilig

11. Hoe communiceert u met uw zorgverleners(s)? *

Onder zorgverlener verstaan wij in dit onderzoek de vrijwillige mantelzorgers: iemand die hulp geeft aan iemand anders. Niet omdat de mantelzorger een hulpverlenend beroep heeft, maar omdat hij/zij een sociale relatie met die persoon heeft. Zoals met een familielid, vriend of buren.

Vink alle toepasselijke opties aan.

- [ ] WhatsApp
- [ ] Telefonisch
- [ ] Enkel mondeling
- [ ] Ik heb geen zorgverlener
- Anders: [ ] ____________

Ga naar vraag 17

Algemene vragen

Algemene vragen voor doelgroep mantelzorgers

12. Hoe zou u de lichamelijke gezondheid beoordelen van degene waarvoor u mantelzorger bent? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Zeer slechte lichamelijke gezondheid	○	○	○	○	○	○	Zeer goede lichamelijke gezondheid

13. Hoe zou u de geestelijke gezondheid beoordelen van degene waarvoor u mantelzorger bent? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Zeer slechte geestelijke gezondheid	○	○	○	○	○	○	Zeer goede geestelijke gezondheid

14. Is degene waarvoor u mantelzorger bent altijd open en eerlijk tegenover u over de geestelijke en lichamelijke gezondheid? *

Markeer slechts één ovaal.

- Ja
- Nee
- Weet ik niet

15. STELLING: Ik heb een sturende/leidinggevende rol in de relatie met de oudere. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

16. Hoe communiceert u met degene die u verzorgt? *

Vink alle toepasselijke opties aan.

- WhatsApp
- Telefonisch
- Enkel mondeling
- Anders: ____________________

Ga naar vraag 29

Valongelukken (1)

Vragen over valongelukken voor de doelgroep ouderen (60+)

17. Heeft u angst om te vallen? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Geen angst							Zeer angstig

18. Gebruikt u op dit moment een product of service om de kans op vallen te verkleinen of de gevolgen van een val te beperken? (noodknop, rollator, etc.) *

Vul in: Nee / Ja, namelijk...

____

19. Doet u verder nog specifieke dingen om de kans op een val te verkleinen? *

Vul in: Nee / Ja, namelijk...

____

20. Hoe vaak bent u gevallen in de afgelopen 2 jaar? *

Markeer slechts één ovaal.

- 0 keer gevallen *Ga naar vraag 34*
- 1 keer gevallen *Ga naar vraag 21*
- 2 keer gevallen *Ga naar vraag 21*
- 2 – 5 keer gevallen *Ga naar vraag 21*
- Meer dan vijf keer gevallen *Ga naar vraag 21*

Valongelukken (2)

Vragen over valongelukken voor de doelgroep ouderen (60+)

21. Bent u wel eens na een val in het ziekenhuis opgenomen geweest? *

Markeer slechts één ovaal.

- Ja
- Nee

22. Wat was de oorzaak van de val? *

____

23. Was de val binnenshuis of buitenshuis? *

Markeer slechts één ovaal.

- Binnenshuis
- Buitenshuis

24. Had u hulp nodig direct nadat u gevallen was of kon u uzelf redden? *

Markeer slechts één ovaal.

- Direct hulp nodig
- Kon mijzelf redden

25. Hoelang duurde het voordat er hulp ter plaatse was?
Deze vraag hoeft u alleen in te vullen als het antwoord op de vorige vraag 'Ja' was. Als het antwoord 'Nee' was, mag u deze vraag overslaan.

Markeer slechts één ovaal.

- 0 minuten – 1 minuut
- 1 minuut – 10 minuten
- 10 minuten – 30 minuten
- Langer dan 30 minuten

26. Hoe heeft u hulp ingeschakeld?

Vink alle toepasselijke opties aan.

- Alarmknop
- Telefonisch
- Er was iemand dichtbij op het moment van de val
- Val-detectie apparaat

Anders: ______

27. Is door de val uw lichamelijke gezondheid verslechterd?

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Niet verslechterd							Zeer erg verslechterd

28. Is u angst voor vallen toegenomen na de laatste val?

Markeer slechts één ovaal.

	1	2	3	4	5	
Geen toename						Zeer erg toegenomen

Ga naar vraag 34

Valongelukken

29. Bent u bezorgd over een mogelijk valongeluk bij degene die u verzorgt? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Zelden bezorgd							Zeer bezorgd

30. Waarom of waardoor bent u bezorgd?
Deze vraag hoeft u alleen in te vullen als u in de vorige vraag heeft aangegeven wel eens bezorgd te zijn.

______

31. Is degene die u verzorgd al eens gevallen? *

Markeer slechts één ovaal.

- Ja, meerdere keren
- Ja, 1 valongeluk
- Nee
- Weet ik niet

32. Was de val veroorzaakt door een persoonsgebonden factoren (medicijngebruik, slecht zicht, beroerte, lichamelijke beperkingen, etc.) of omgevingsgebonden factoren (struikelen over een stoeptegel, gladde vloer, losliggende mat, opstappen fiets etc.)?
Deze vraag hoeft u alleen te antwoorden als het antwoord op de vorige vraag "Ja,.." was.

______

33. STELLING: Ik kan goed inschatten of er sprake is van een verhoogd val-risico bij degene die ik verzorg (bijvoorbeeld door een afwijkend looppatroon). *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

Ga naar vraag 41

Technologie

Vragen over technologie voor de doelgroep ouderen (60+)

34. Heeft u een smartphone? *

Markeer slechts één ovaal.

- Ja
- Nee

35. STELLING: Ik gebruik dagelijks verschillende apps op mijn smartphone. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

36. STELLING: Het gebruik van nieuwe technologie kan mijn leven eenvoudiger maken. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

37. STELLING: Wanneer ik nieuwe technologie gebruik, moet ik ondersteund worden door zorgprofessionals. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

38. STELLING: Ik vind het gebruik van nieuwe technologie in de gezondheidszorg een goede ontwikkeling. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

39. STELLING: Mensen die belangrijk zijn bij de dienstverlening voor mijn gezondheid, zoals verpleegkundigen en zorgverleners, vinden dat ik technologische applicaties zou moeten gebruiken. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

40. STELLING: Ik ben op de hoogte van de laatste technologische ontwikkelingen. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

Ga naar vraag 49

Technologie

Vragen over technologie voor de doelgroep mantelzorgers

41. Heeft u een smartphone? *

Markeer slechts één ovaal.

- Ja
- Nee

42. STELLING: Ik gebruik dagelijks verschillende apps op mijn smartphone. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

43. STELLING: Ik ben thuis in nieuwe technologie. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens							Sterk mee eens

44. STELLING: Ik vind het gebruik van nieuwe technologie in de gezondheidszorg aangenaam. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	○	○	○	○	○	○	Sterk mee eens

45. STELLING: Wanneer degene waarvoor ik mantelzorg nieuwe technologie gebruikt, moet hij/ zij ondersteund worden door zorgprofessionals. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	○	○	○	○	○	○	Sterk mee eens

46. STELLING: Het gebruik van eenvoudige nieuwe technologie kan ik uitleggen aan de ouderen (70+) waarnaar zij in staat zijn de nieuwe eenvoudige technologie zelfstandig te gebruiken. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	○	○	○	○	○	○	Sterk mee eens

47. In welke mate speelt de angst voor stigmatisering bij hulpbehoevende ouderen een rol bij het accepteren van zichtbare hulpmiddelen? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Speelt geen rol	○	○	○	○	○	○	Speelt zeer grote rol

Ga naar vraag 48

Valdetectie

Vragen over val-detectie voor de doelgroep mantelzorgers.

48. STELLING: Het dragen van een goed werkend val-detectie apparaat door degene voor wie ik mantelzorg, geeft mij meer rust en een zekerder gevoel. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	○	○	○	○	○	○	Sterk mee eens

Val-detectie (1)

Vragen over val-detectie voor beide doelgroepen

49. Welke van de opties voor het dragen van een val-detectie systeem (voor ouderen) spreekt u het meest aan? Val-detectie verwerkt in... *

Vink alle toepasselijke opties aan.

- ☐ Horloge
- ☐ Ketting
- ☐ Schoen(zool)
- ☐ Gehoorhoorapparaat
- ☐ Smartphone
- ☐ Riem / Broekclip
- ☐ Niet zichtbaar bij het dragen
- Anders: ☐ ____________________

50. Wie moet volgens u het eerst gealarmeerd worden na een val? *

Markeer slechts één ovaal.

- ○ Niemand
- ○ Hulpcentrale
- ○ Mantelzorger
- ○ Familie
- ○ Partner
- ○ Ter plekke bepalen door de gevallen persoon
- ○ Anders: ____________________

Val-detectie (2)

Vragen over val-detectie voor beide doelgroepen.

De volgende vragen zullen bestaan uit enkele stellingen over val-detectie. Graag per vraag aangeven in welke mate u het eens bent met de stelling, ook als u zelf niet tot de doelgroep van een val-detectie apparaat behoort.

51. STELLING: Het val-detectie apparaat moet weten waar de gebruiker van het val-detectie apparaat zich bevindt. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

52. STELLING: Het val-detectie apparaat mag een alarm uitsturen na een val zonder toestemming van de gebruiker. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

53. STELLING: Het val-detectie apparaat mag bewegingsdata verzamelen en onthouden hoevaak, waar en wanneer de gebruiker gevallen is. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

54. STELLING: Het val-detectie apparaat moet ook te gebruiken zijn als de gebruiker in bed ligt. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

55. STELLING: Het val-detectie apparaat moet spraak gestuurd zijn. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

56. STELLING: Het val-detectie apparaat moet onder de douche te gebruiken zijn (waterdicht). *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

57. STELLING: Een val-detectie apparaat moet modieus zijn. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

58. STELLING: Het val-detectie apparaat moet gekoppeld zijn aan een smartphone-app voor extra services (GPS, resterende batterijduur, chatfunctie zorgverlener / familie, etc.) *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Sterk mee oneens	◯	◯	◯	◯	◯	◯	Sterk mee eens

59. Welke van de volgende services hebben volgens u een toegevoegde waarde aan het val-detectie apparaat? *

Vink alle toepasselijke opties aan.

- ☐ Het aantal keren vallen bijhouden
- ☐ Routebegeleiding locatie-tracker
- ☐ Locatieregistratie
- ☐ Resterende batterijduur weergeven
- ☐ Coaching bij val-preventie oefeningen
- ☐ Waarschuwingsfunctie voor geregistreerde toename in instabiliteit / afwijkend looppatroon
- ☐ Communicatiefunctie met zorgverlener / familie / buren

Anders: ☐ ____________________

60. Wat maakt volgens u een val-detectie apparaat gebruiksvriendelijk? *

____

61. Wat vindt u een redelijk bedrag voor een val-detectie apparaat? *

Markeer slechts één ovaal.

- €50 - €80
- €80 - €100
- €100 - €150
- €150 - €200
- €200 - €300
- Meer dan €300

Einde enquête

Hartelijk dank voor uw interesse om deel te nemen aan dit onderzoek en het invullen van de enquête.

62. Heeft u adviezen / tips / opmerkingen die niet aan bod zijn gekomen in de enquête waarmee u mij kunt helpen bij dit onderzoek?

63. Mag er eventueel contact met u opgenomen worden voor verdere vragen naar aanleiding van de ingevulde enquête? Zo ja, vul dan hier uw e-mail en/of telefoonnummer in;

De persoonsgegevens die u eventueel invult, worden zorgvuldig verzameld en zullen enkel gebruikt worden voor onderzoeksdoeleinden. Onder geen enkele voorwaarde zullen deze persoonsgegevens gedeeld worden met derde partijen voor bijvoorbeeld reclamedoeleinden.

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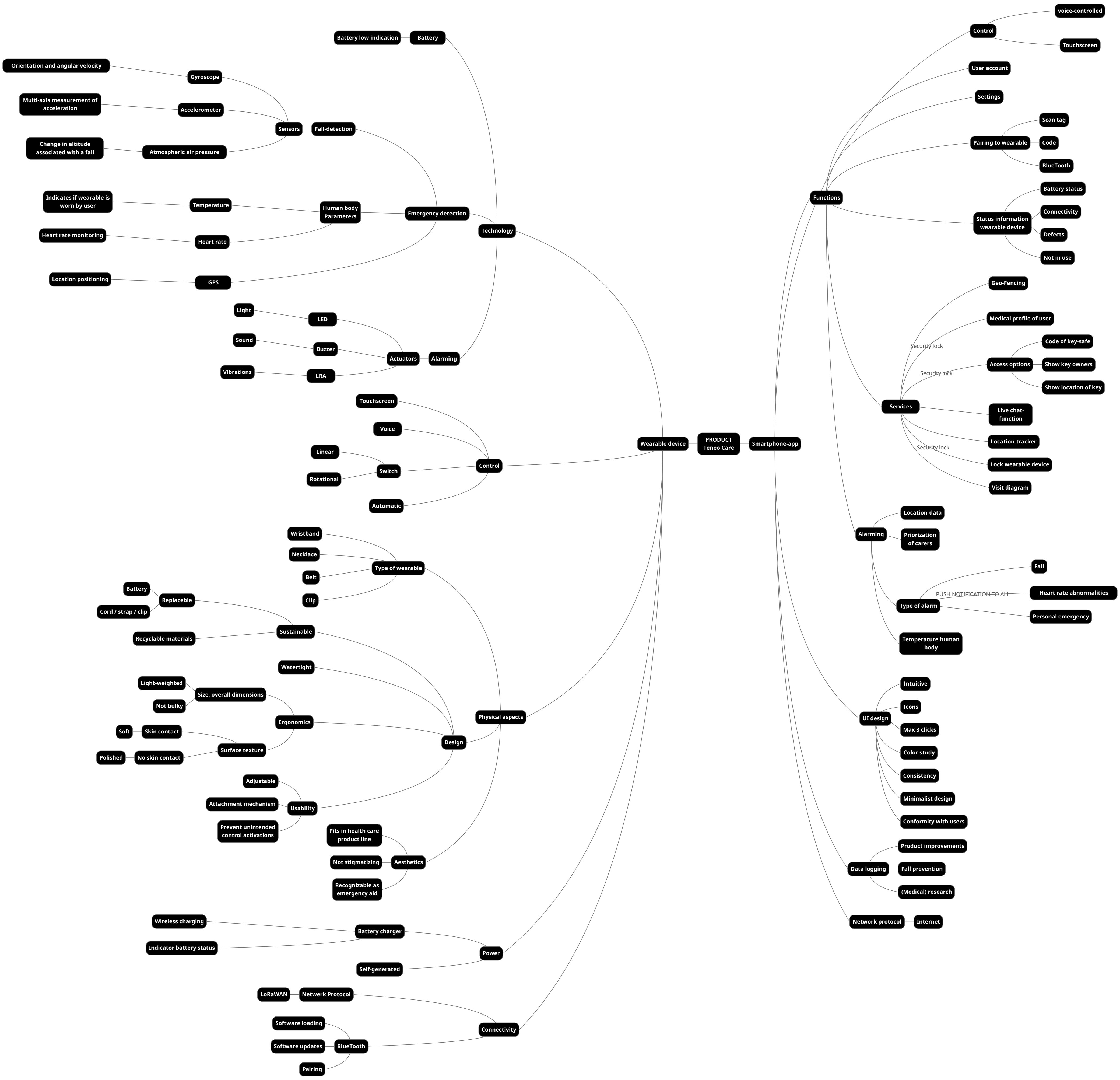
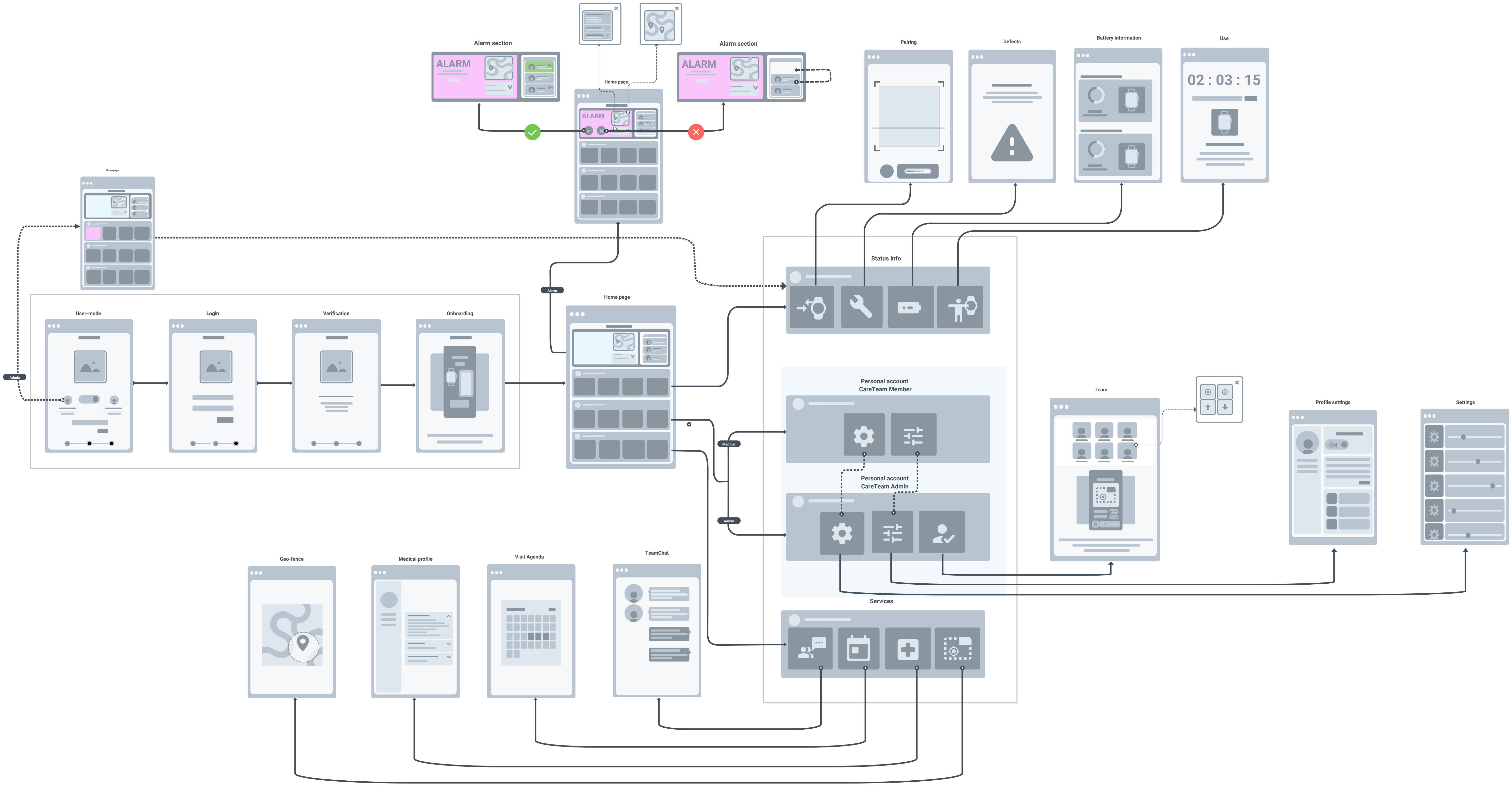
Appendix C Brainstorm Mind map [Ideation]



Appendix D Wireframe user flow [Specification]



Appendix E Final requirements [Specification]

MUST			
Functional requirements	**P**	M1	The product MUST consist of a wearable device with a wireless charger and corresponding smartphone-app.
	W	*M1.1*	It MUST be possible to place the wearable device in ***different supporting wearing systems.***
	W	*M1.2*	***The wearable device MUST be a modular interchangeable module that can be placed in different supporting wearing systems without using any tools.***
	P	M2	The wearable device MUST have two-way communication with the corresponding smartphone-app.
	W	M3	It MUST be clear to (a hearing and/ or visually impaired) user of the wearable device that the system has detected a (possible) fall / emergency.
	W	*M3.1*	*The wearable device MUST have a light actuator.*
	W	*M3.2*	*The wearable device MUST have a sound actuator.*
	W	*M3.3*	*The wearable device MUST have a vibration actuator.*
	W	M4	If after detecting a (possible) fall / emergency the user has not interacted with the wearable device within ***10 seconds*** an alarm MUST automatically be sent to the corresponding smartphone app.
	P	M5	The product MUST have a provision to detect heart rate abnormalities.
	W	*M5.1*	*If no heart rate or heart rate abnormalities are detected by the wearable device* ***during 20 seconds****, an emergency alarm MUST be issued.*
	A	*M5.2*	***In case of an emergency alarm*** *a push notification MUST be send to the smartphone app users who have a resuscitation competence and/or access to an AED.*
	W	M6	The user MUST be able to use the wearable device without having complicated interaction.
	W	*M6.1*	*The user MUST be able to control the wearable device by* ***a momentary push button***
	P	M7	The status-information of the wearable device MUST be visible.

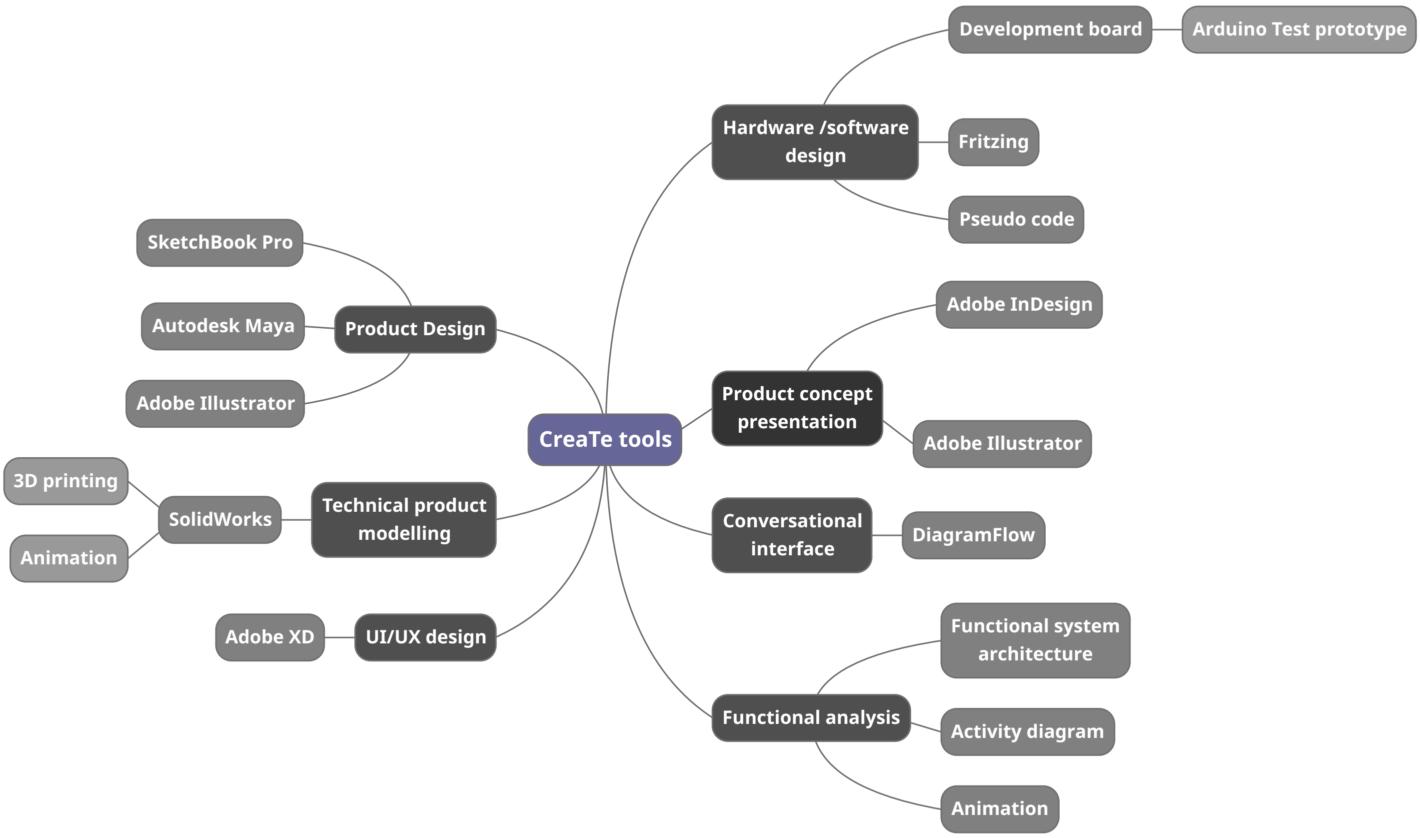
	P	*M7.1*	*Low battery indication MUST be visible on the wearable device and* on *the smartphone app .*
	P	M7.2	*Low battery indication MUST be true when the operating time **is less than 24 hours.***
	A	*M7.3*	*The availability of the wearable device MUST be visible in the smartphone-app.*
	A	*M7.4*	*A defect of the wearable device MUST be visible in the smartphone-app.*
	A	*M7.5*	*Disruption of the connectivity of the wearable device MUST be visible in the smartphone-app.*
	A	M8	The smartphone-app MUST include a list of carers who are alerted automatically in case of an emergency on a call-by-call basis in the sequence of the predefined list.
	A	*M8.1*	*If there is no response of the smartphone-app user who is alerted in case of an emergency **within 60 seconds**, the next person in the predefined list MUST be alarmed.*
	P	M9	In case of an alarm the product MUST show the location of the user of wearable device.
	W	*M9.1*	*The wearable device MUST be able to send location positioning information to the smartphone-app.*
	A	M9.2	*The smartphone-app MUST be able to display location position data of the wearable device after an alarm.*
Non-functional requirements	**W**	M10	One or more sensors MUST be implemented in the wearable device to detect a fall.
	W	*M10.1*	*The wearable device MUST be able to measure orientation and angular velocity.*
	W	*M10.2*	*The wearable device MUST be able to measure multi-axis acceleration.*
	W	*M10.3*	*The wearable device MUST be able to measure atmospheric air pressure.*
	W	M11	One or more sensors MUST be implemented in the wearable device to measure human body parameters.
	W	*M11.1*	*The wearable device MUST be able to measure heart rate and to detect heartrate abnormalities.*
	W	*M11.2*	*The wearable device MUST be able to measure body temperature.*
	W	M12	The wearable device MUST be usable by older adults with a visual and / or hearing impairment and / or deteriorated physical health (parkinson, artrosis, heart diseases) / mental health (forgetfulness, dementia) .
	W	*M12.1*	*The wearable device MUST be controllable by older adults with a visual and / or hearing impairment and / or deteriorated physical / mental health.*

	W	*M12.2*	*The wearable device MUST be put on/put off without the help of others.*
	W	*M12.3*	*Unintended activation of control functions MUST be prevented.*
	C	M13	The wearable device MUST be wireless rechargeable.
	W	*M13.1*	*The wearable device MUST have a battery* ***low*** *status indicator.*
	W	*M13.2*	***Battery low status MUST be true in case less than 24 hours of operation time is left.***
	W	*M13.3*	***In case of battery low, the wearable device MUST generate every 8 hours an acoustic-, vibration- and light signal during 5 seconds until the wearable device is connected to the wireless charger.***
	W	*M13.4*	***In case the wearable device is placed on the wireless charger and the battery is charged to maximum capacity the wearable device MUST generate every 60 seconds an acoustic-, vibration- and light signal during 5 seconds until the wearable device is put on the wrist.***
	W	*M13.5*	***The wearable device MUST be fully recharged within 1 hour.***
	w	*M13.6*	*The battery of the wearable device MUST guarantee* ***an operation time of 72 hours.***
	P	M14	Network LoRaWAN MUST be used for connectivity.
	P	M15	**LoRaWAN** MUST be used for software loading, software updates and product settings.
	P	M16	Data - and privacy protection MUST be implemented.
	W	M17	The wearable device MUST be able to send location positioning data.
	W	M18	The wearable device MUST be water resistant.
	P	M19	It MUST be possible to use the wearable device also as an emergency alarm, even if there has not been a fall accident.
	W	*M19.1*	*The wearable device MUST have a manual alarm control.*
SHOULD			
Functional requirements	**A**	S1	The smartphone-app users SHOULD be able to change their availability for help by themselves.
	W	S2	The wearable device SHOULD include the option to lock the attachment mechanism.

	W	S2.1	***It SHOULD be possible to lock the wristband. The locked wristband can only be put off with the help of a carer.***
	A	S3	The smartphone-app SHOULD have special functions for the administrator.
	A	*S3.1*	*The administrator SHOULD be able to add and delete smartphone-app users.*
	p	*S3.2*	*The administrator SHOULD be able to pair the new wearable device to the smartphone-app.*
	A	*S3.3*	*The administrator SHOULD be able to change the priority list.*
Non-functional requirements	**A**	S4	The cognitive effort of the smartphone-app user SHOULD be minimized by simplifying data into an easy understandable intuitive representation of the GUI.
	A	*S4.1*	*The smartphone-app SHOULD use visual language, such as icons, where possible.*
	A	*S4.2*	*Every action SHOULD be activated within 3 clicks.*
	A	*S4.3*	*There SHOULD be consistency (color, font, etc.) in GUI.*
	A	*S4.4*	*The design of the GUI SHOULD be minimalist (only essential information will be showed).*
	P	S5	The product SHOULD be able to be used nationwide.
	P	*S5.1*	*The product SHOULD not be dependent on a local emergency care call center.*
	W	*S6*	The wearing comfort / ergonomics of the wearable SHOULD be tailored to the target group.
	W	*S6.1*	*The surface texture SHOULD be soft and non-irritating where skin contact and polished where no skin contact.*
	W	*S6.2*	*The weight SHOULD not exceed **50 gram**.*
	W	*S6.3*	*The wearable device SHOULD be adjustable without assistance.*
	W	*S6.4*	***The size SHOULD not exceed 40 mm diameter and height 15 mm***
	P	*S7*	The selling price of the product including wearable device, wireless charger and ***6 accounts*** *for the* smartphone-app SHOULD ***not exceed €500****.*
	P	*S8*	The look and feel / aesthetics of the product SHOULD reflect how it is put into the market, namely via healthcare-related platforms / shops.
	P	*S9*	The product SHOULD not be stigmatizing.
		S10	The smartphone app SHOULD provide information on how to enter the house of the user of the wearable device.
COULD			

Functional requirements	**P**	*C1*	The product COULD be voice controlled.
	P	*C2*	The product COULD be able to make an automatic emergency call (112).
	A	*C3*	The carers COULD be able to communicate with each other via live chat function in the smartphone-app.
	A	*C4*	The smartphone-app COULD include a secured medical profile of wearable device user for health professionals (ambulance personnel and doctors).
	A	*C5*	The smartphone-app COULD have integrated geo-fencing functionality which can only be set by the administrator.
	P	C6	The product COULD be able to store monitored data.
	P	*C6.1*	*Data logging COULD be used for product improvements.*
	P	*C6.2*	*Data logging COULD be used for fall-prevention.*
	P	*C6.3*	*Data logging COULD be used for (medical) research.*
	P	*C7*	*The product COULD be able to send an alert if the body temperature of the person wearing the wearable device is over 38℃ for more than 3 hours (COVID-19)*
Non-functional requirements	**P**	C8	The product COULD be sustainable.
	W	*C8.1*	*Materials COULD be recyclable.*
	W	*C8.2*	*The cord / strap / clip COULD be replaceable.*
	W	*C8.3*	*The battery COULD be replaceable.*
WON'T			
Functional requirements	**P**	W1	The product WON'T provide language settings.
Non-functional requirements	**A**	W2	De smartphone-app WON'T be used in professional care institutions.
	W	W3	The product WON'T give the user the possibility to switch the wearable device off.
	P	W4	The product WON'T give direct instructional feedback on how to improve gait and balance.
	P	W5	The product WON'T have multiple wearable devices linked to one smartphone-app.

Appendix F Tools for realization [Realization]



Appendix H Hardware components [Realization]

Table 1: Components integrated on the Teneo Nano board.

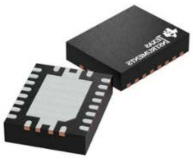
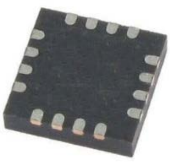
Hardware component	**Description**	**Type and manufacturer**
LoRaWAN 	*LoRaWAN is a Low Power Wide Area Network (LPWAN). Specially developed for wireless battery-operated products in a regional, national or global network.* https://www.hoperf.com/modules/lora/RFM95.html	- LoRa Module RFM95W module - Manufactured by HopeRF
GPS Receiver 	*The GPS receiver has an embedded Patch Antenna and LNA. L80 is a full featured GPS module with super sensitivity. It is characteristic of low power consumption and compact size.* *https://nl.rs-online.com/web/p/gps-chips-gps-modules/9084085/*	- L80M39 GPS module - manufactured by Quectel
Accelerometer 	*Accelerometer is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum to full-scale range of ±3 g.* *https://nl.mouser.com/datasheet/2/609/ADXL335-1503897.pdf*	- The ADXL326 - manufactured by Analog Devices
Temperature sensor 	*Temperature sensor in TO-92 casing* *Operating temperature: -40 - +126 °C* *10 mV/°C scale factor* *https://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf*	- Temperature sensor TMP36GT9Z - manufactured by Analog Devices
Wireless charging 	*For battery charging a highly Integrated Wireless Receiver is used. The Wireless Receiver is connected to a charging coil with ferrite which is not integrated on the Teneo-Nano board.* *http://www.ti.com/lit/ds/slusb62/slusb62.pdf*	- Wireless Receiver Qi (WPC V1.1) - manufactured by Texas Instruments

Table 2: Auxiliary components of the wearable device

Hardware component	Description	Type and manufacturer
LoRaWAN antenna 	*The LoRaWAN has an additional PCB antenna.* *Dimensions: 22 x 6.5 x 1.6 mm* https://www.delock.com/produkte/S_12540/merkmale.html	- Type - Manufactured by Delock -
Rechargeable Battery 	*Battery, 3 V, 2450, Lithium Manganese Dioxide, 620 mAh.* *Dimensions rechargeable Battery* https://www.panasonic.com/nl/	- CR-2450/BS - Manufactured by Panasonic
Charging coil 	*Description* *Dimensions charging coil with ferrite: length 16 mm and diameter 3 mm.* **Fout! De hyperlinkverwijzing is ongeldig.**	- Type - Manufactured by - Wurth Elektronik
Pressure Sensor 	A small metal package pressure sensor with a watertight sealing is used. Dimensions: 3.3 x 3.3 x 2.75mm *https://nl.mouser.com/datasheet/2/418/5/NG_DS_MS5837-02BA01_A5-1392995.pdf*	- Type - Manufactured by TE Connectivity
Gyroscope 	The motion sensor is a 3-axis digital output gyroscope. Dimensions: 4x4x1mm *https://www.st.com/resource/en/datasheet/i3g4250d.pdf*	- I3G4250D MEMS - Manufactured by ST Life
Heart rate sensor 	Integrated Heart-Rate Sensor designed for the demanding requirements of mobile, wearable devices. It is optimized to detect Heart Rate (HR), Oxygen Saturation (SpO2), and Heart Rate Variability (HRV). Dimensions: 4.3mmx2.8mmx1.45mm https://datasheets.maximintegrated.com/en/ds/MAX86160.pdf	- Maxim MAX86160 - Manufactured by Maxim Integrated

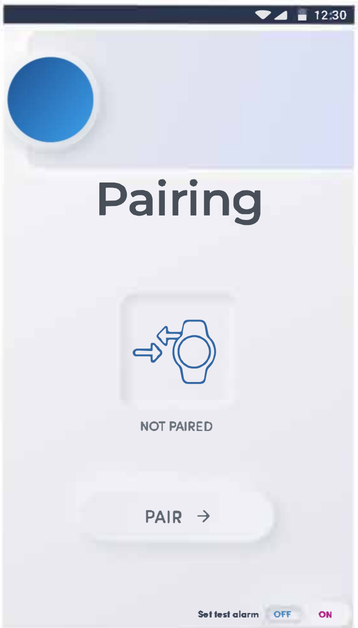
Vibration motor 	DC Vibration motor, ERM 15000 RPM Z30C1T8460001 Dimensions: diameter 4 mm, length 10 mm *https://www.digikey.com/product-detail/en/jinlong-machinery-electronics-inc/Z30C1T8460001/1670-1031-1-ND/6570603*	- Type - Manufactured by Jinlong Machinery & Electronics, Inc.
Buzzer 	For the buzzer function a small SMD piezo Buzzer is used. Resonant Frequency: 4000±500Hz square wave, Sound Pressure Level: ≥65dB@10cm Dimensions: 9 x 9 x 1.8 mm https://www.manorshi.com/3V-65db-9-9-1-8mm-SMD-small-piezo-Buzzer-pd45972806.html	- Type - Manufactured by Manorshi
Push button switch 	Ultra-thin Buttonless Film Touch Button Tact Switch. Dimensions: 7 x 7.5 x 0.5mm *https://www.gangyuantech.com/tactile-switch_c6?gclid=EAIaIQobChMI7dKnrYjU6gIVBc93Ch1D9gcdEAMYAyAAEgIA-_D_BwE*	- Type KAN0545 - Manufactured by Wenzhou Gangyuan

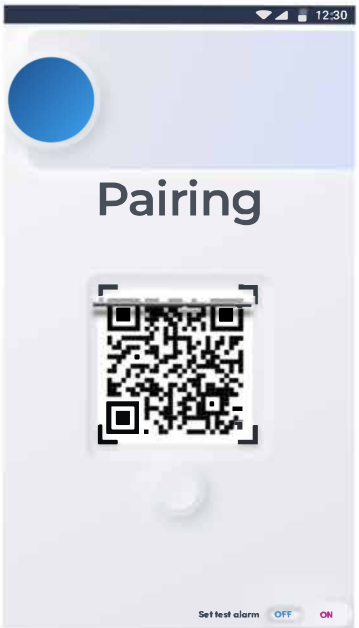
Appendix G Smartphone App screens [Realization]

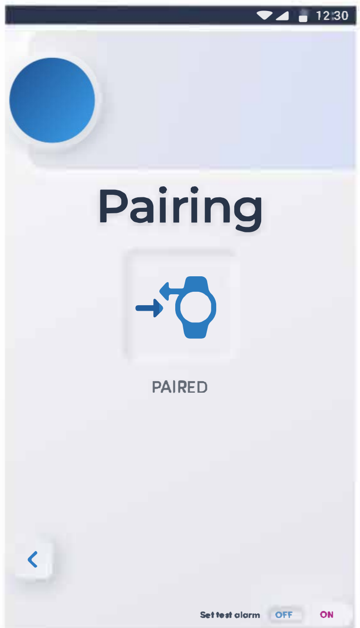
Welcome

Login

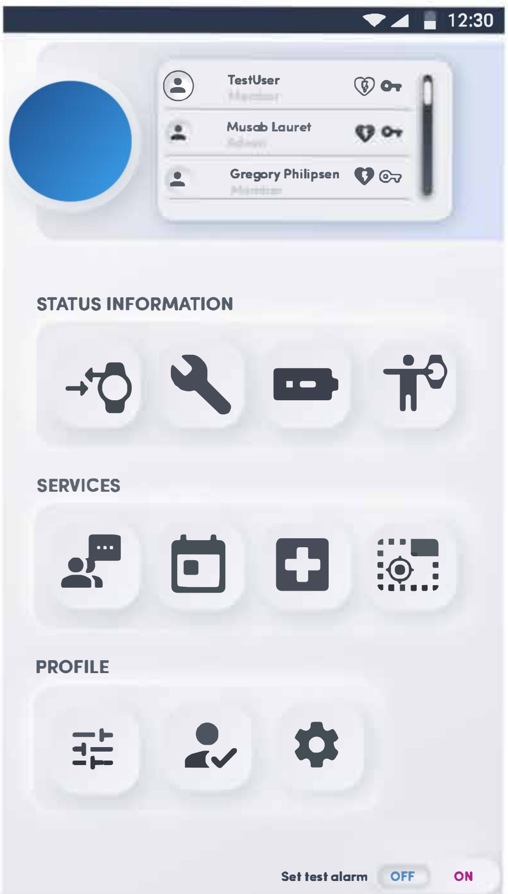
Pairing



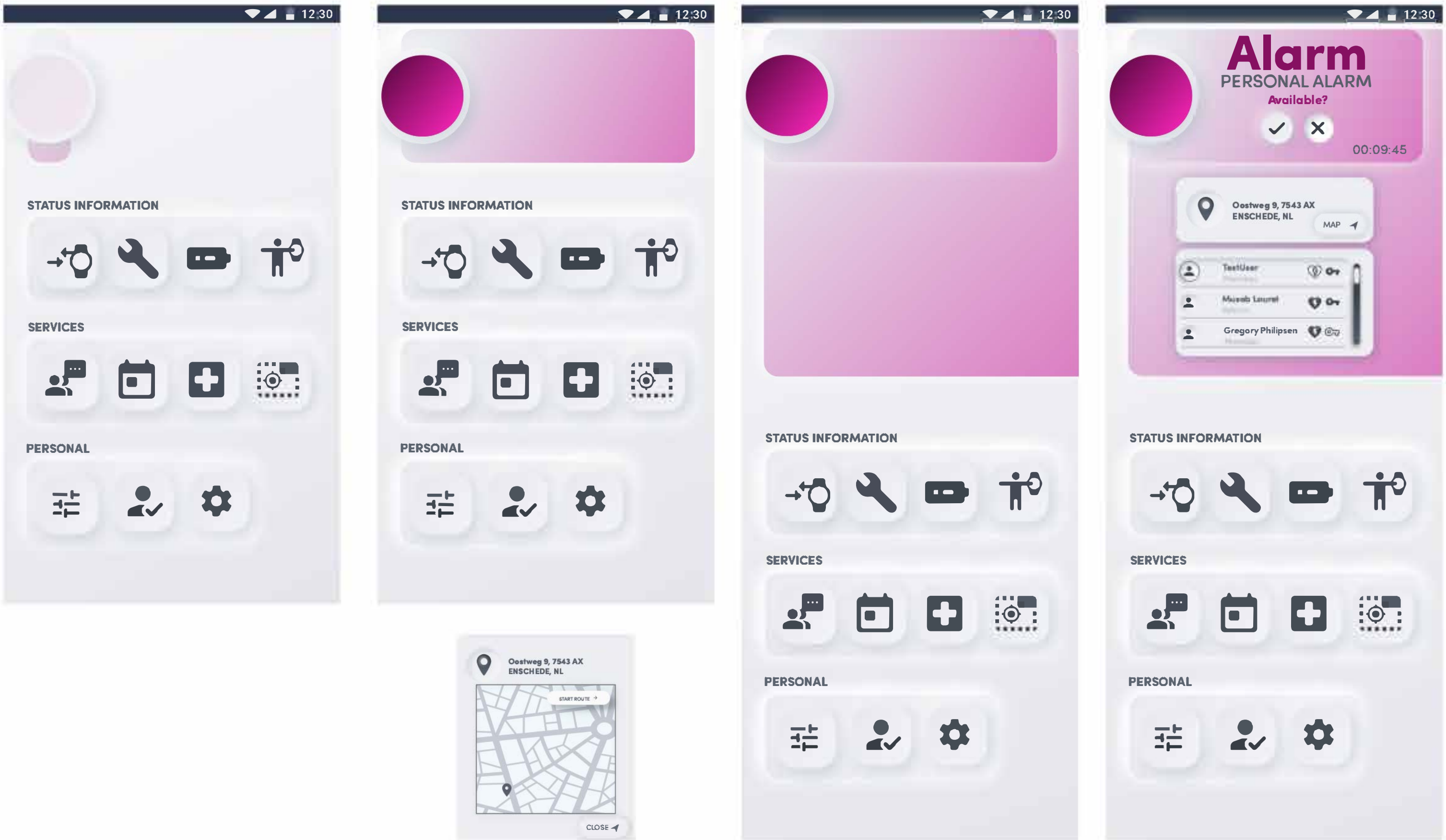




Home Dashboard

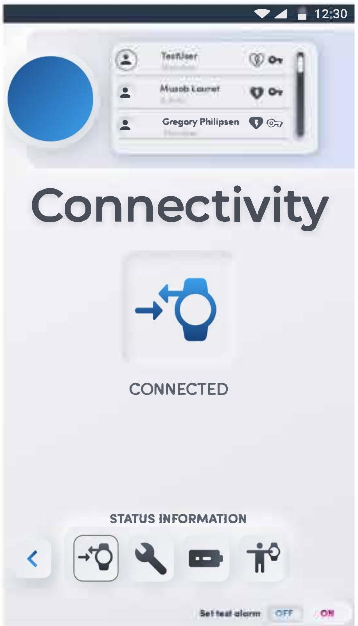


Alarm modus

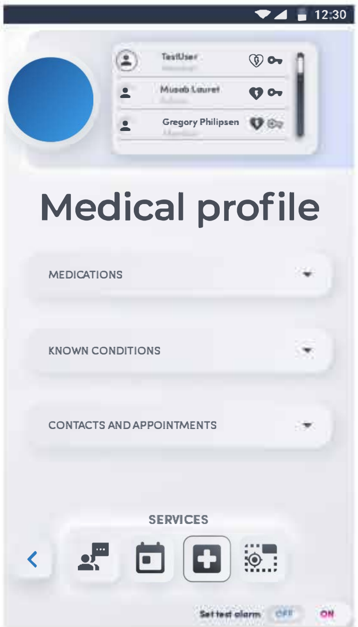

12:30
STATUS INFORMATION
SERVICES
PERSONAL
Alarm
PERSONAL ALARM
Available?
00:09:45
Oostweg 9, 7543 AX
ENSCHEDE, NL
MAP
TestUser
Musab Lauret
Gregory Philipsen
CLOSE


12:30
Alarm
PERSONAL ALARM
Care provided?
NO
YES
00:09:45
Oostweg 9, 7543 AX
ENSCHEDE, NL
MAP
(28)88 452206
CALL
TestUser
Musab Lauret
Gregory Philipsen
Roza Lindenboom
STATUS INFORMATION
SERVICES
PERSONAL
Set test alarm
OFF
ON

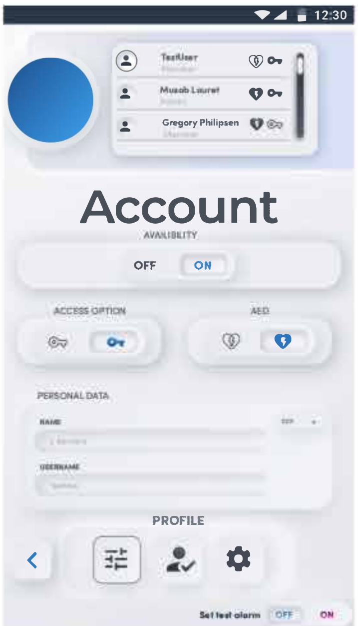
Status information

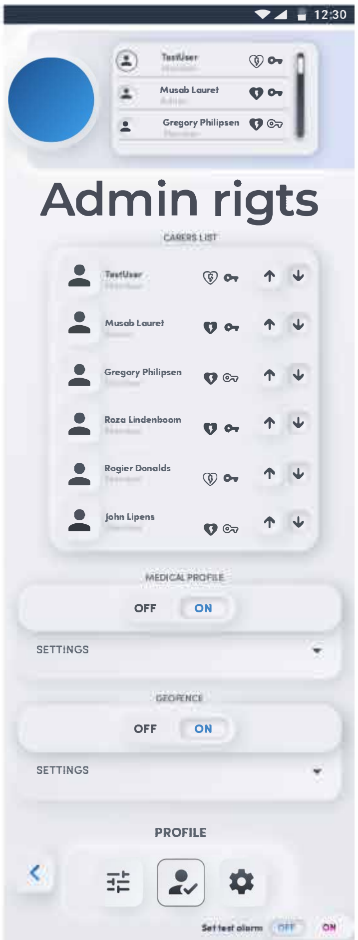


Services



Profile





Appendix I Expert evaluation session [Evaluation]

Toestemmingsverklaring

---Wat wordt er van u verwacht?
U neemt deel aan een semi-gestructureerde evaluatie sessie waarin aan u open en gesloten vragen zullen worden gesteld over het onderzoeksproject conceptueel ontwerp van een 'nieuw user-driven valdetectiesysteem voor ouderen'. De onderwerpen die besproken zullen worden zijn: polsband met valdetectiesysteem en smartphone app.

Van het interview zal een audio- en video opname worden gemaakt, zodat het gesprek later ad-verbum (woord voor woord) kan worden uitgewerkt. Dit transcript wordt vervolgens gebruikt in het verdere onderzoek. Voordat de onderzoeksgegevens naar buiten gebracht worden, worden uw gegevens anoniem gemaakt. In een publicatie of presentatie zullen de anonieme gegevens worden gebruikt.

U dient tenminste 16 jaar te zijn om deel te nemen aan dit onderzoek.

---Vrijwilligheid
U doet vrijwillig en anoniem mee aan dit onderzoek. Daarom kunt u op elk moment tijdens het onderzoek uw deelname stopzetten en uw toestemming intrekken.
Wat gebeurt er met mijn gegevens?
De onderzoeksgegevens die in dit onderzoek verzameld worden, zullen enkel gebruikt worden voor dit onderzoek als informatieve methode om het probleem en het doelpubliek te begrijpen. De gegevens zullen anoniem gemaakt worden en blijven. Alle onderzoeksgegevens worden op beveiligde wijze volgens de richtlijnen van de Universiteit Twente bewaard.

---Heeft u vragen/opmerkingen over het onderzoek?
Als u meer informatie over het onderzoek wilt, kunt u contact opnemen met Carlijn Rendering.

Telefoon: +31 6 30207706;
Adres: Beethovenstraat 20, 7131AK Lichtenvoorde
E-mail: c.rendering@student.utwente.nl

Mocht u klachten hebben over dit onderzoek, dan kunt u deze richten aan de secretaris van de Commissie Ethiek van de Faculteit der Elektrotechniek, Wiskunde en Informatica van de Universiteit Twente, postbus 217, 7500 AE Enschede (NL), email: ethics-comm-ewi@utwente.nl).

1. Naam participant

____

2. Datum

____

Voorbeeld: 7 januari 2019

3. Door te klikken op de knop 'Ik ga akkoord' geeft u aan dat u de bovenstaande informatie heeft gelezen, vrijwillig meedoet aan het onderzoek en 18 jaar of ouder bent. *

Markeer slechts één ovaal.

- ◯ Ik ga akkoord
- ◯ Ik ga niet akkoord

Evaluation - face-to-face session (semi-structured)

Stakeholder: Owners Teneo-IoT B.V.

1 - Informatiebrochure en toestemmingsverklaring

Openingsstatement
'Onderzoek en conceptueel ontwerp van een nieuw user-driven valdetectiesysteem voor ouderen' *Bacheloropdracht Creative Technology 2020* *Carlijn Rendering, s1964437* *c.rendering@student.utwente.nl* *U wordt uitgenodigd om mee te doen aan een bachelor afstudeeronderzoek naar val-gerelateerde technologieën voor ouderen. Het doel van dit onderzoek is het ontwerpen van een conceptueel design voor een nieuw valdetectie product voor ouderen (70+). Het afstudeeronderzoek wordt uitgevoerd voor de opleiding Creative Technology in samenwerking met Teneo-IoT B.V.*

Toestemmingsverklaring
Wat wordt er van u verwacht? U neemt deel aan een semi-gestructureerde evaluatie sessie waarin aan u open en gesloten vragen zullen worden gesteld over het onderzoeksproject *conceptueel ontwerp van een 'nieuw user-driven valdetectiesysteem voor ouderen'*. De onderwerpen die besproken zullen worden zijn: polsband met valdetectiesysteem en smartphone app. Van het interview zal een audio- en video opname worden gemaakt, zodat het gesprek later ad-verbum (woord voor woord) kan worden uitgewerkt. Dit transcript wordt vervolgens gebruikt in het verdere onderzoek. Voordat de onderzoeksgegevens naar buiten gebracht worden, worden uw gegevens anoniem gemaakt. In een publicatie of presentatie zullen de anonieme gegevens worden gebruikt. U dient tenminste 16 jaar te zijn om deel te nemen aan dit onderzoek. **Vrijwilligheid** U doet vrijwillig en anoniem mee aan dit onderzoek. Daarom kunt u op elk moment tijdens het onderzoek uw deelname stopzetten en uw toestemming intrekken. **Wat gebeurt er met mijn gegevens?** De onderzoeksgegevens die in dit onderzoek verzameld worden, zullen enkel gebruikt worden voor dit onderzoek als informatieve methode om het probleem en het doelpubliek te begrijpen. De gegevens zullen anoniem gemaakt worden en blijven. Alle onderzoeksgegevens worden op beveiligde wijze volgens de richtlijnen van de Universiteit Twente bewaard.

Heeft u vragen/opmerkingen over het onderzoek? Als u meer informatie over het onderzoek wilt, kunt u contact opnemen met Carlijn Rendering. *Telefoon: +31 6 30207706;* *Adres: Beethovenstraat 20, 7131AK Lichtenvoorde* *E-mail: c.rendering@student.utwente.nl* Mocht u klachten hebben over dit onderzoek, dan kunt u deze richten aan de secretaris van de Commissie Ethiek van de Faculteit der Elektrotechniek, Wiskunde en Informatica van de Universiteit Twente, postbus 217, 7500 AE Enschede (NL), email: ethics-comm-ewi@utwente.nl). Door te klikken op de knop **'Ik ga akkoord'** geeft u aan dat u de bovenstaande informatie heeft gelezen, vrijwillig meedoet aan het onderzoek en 18 jaar of ouder bent.

→ Versturen via mail

2 - Inleidende beschrijving afstudeeronderzoek

Mondelinge uitleg over afstudeerproject + afbeeldingen laten zien.

Uitleg bachelor afstudeeronderzoek
Deze bachelorscriptie richt zich op het ontwikkelen van een valdetectiesysteem voor ouderen. Dit valdetectiesysteem kan tevens de hartslag van de gebruiker monitoren en kan een alarm afgeven bij abnormale hartritmes en hartstilstand. Het systeem bestaat uit drie delen: - Polsband met het valdetectiesysteem (voor de ouderen) - Gekoppelde app voor de smartphone (voor de verzorgenden) - Draadloze oplader (voor de polsband) AFBEELDINGEN INVOEGEN **Polsband met valdetectiesysteem** De polsband kan detecteren of iemand gevallen is en kan tevens hartslag afwijkingen registreren en melden. Er zijn drie situaties mogelijk: - de oudere heeft hulp nodig en kan zelf de alarmknop indrukken waardoor een alarm naar de app gezonden wordt - de oudere is gevallen en er wordt automatisch een alarm gestuurd, tenzij de oudere binnen 10 seconden de alarmknop indrukt om het alarm niet te verzenden - de polsband detecteert een abnormaal of geen hartritme, er wordt direct automatisch een pushbericht naar de app gestuurd. **Gekoppelde smartphone-app** Elke gebruiker van de polsband is middels de bijbehorende smartphone-app gekoppeld aan een groep van zorgverleners. Deze zorgverleners werken samen in de app. Binnen de groep is één persoon de 'admin' met speciale rechten/privileges en de rest zijn 'team members'. De activiteiten op de smartphone-app voor de 'admin' als 'team members' zullen bestaan uit bijvoorbeeld: aangeven of de verzorgers momenteel beschikbaar zijn voor hulp of niet en het invoeren van bezoekafspraken met de oudere. De speciale activiteiten die alleen de 'admin' kan uitvoeren zijn

bijvoorbeeld: het up-to-date houden van de lijst met verzorgers, het invoeren van de juiste volgorde waarin de verzorgers worden gewaarschuwd, instellen van de straal van de geofence (een gebied waarin de oudere zich kan begeven en waarbij een melding gegeven wordt als de oudere buiten dit gebied gaat), instellen welke services er gebruikt worden. Via de app kunnen de verzorgers met elkaar communiceren.

3 - Algemeen

Onderwerp	Notities
Expertise	
Ervaringen met mantelzorg	
Verwachtingen vooraf - Minimale eisen - Gebruiksvriendelijkheid	

4 - Polsband met valdetectiesysteem

Laten zien van het ontwerp van de polsband en beschrijving ervan geven.

Onderwerp	Notities
‘Look & feel’ / ontwerp / design	
Modulaire opbouw	
Technische haalbaarheid	
Opladen	
Interactie tijdens alarmsituatie	
Sluitingsmechanisme	
Stigmatisering	

5 - Smartphone-app

Inleidende uitleg geven over mock-up smartphone-app:

- Afhankelijk input data buitenaf
- Nog niet alle interactie gerealiseerd

Opdrachten

Opdracht	Notities
Inloggen als admin	
Pairing	

Home dashboard	
Alarm sectie (alarm uit) - Aantal mensen toegang tot woning - Aantal mensen AED - Wie eerste gewaarschuwd - Hoeveel mensen in 'carers list' - Wie is niet beschikbaar	
Alarm sectie (alarm aan) - Aangeven beschikbaar zijn - Locatie bekijken - Telefoonnummer - Beschrijving wat er gebeurt - Aangeven niet beschikbaar te zijn - Beschrijving wat gebeurt in 'carers list'	
Instellen geofence - Invloed op vrijheid	
Inloggen medisch profiel - Privacy issues	
Use - Zekerder gevoel?	
Visit agenda - Toegevoegde waarde?	
Battery status - Hoeveel tijd resteert om de batterij op te laden?	
---5 minuten zelfstandig testen van de app---	

Onderwerpen voor evaluatie

Onderwerp	**Notities**
'Onboarding'/introducerende tour/ingebouwde handleiding	
"Look & feel" / Design - Neumorphism - Logo	
Kleurstelling	
Iconen	
Lettertype	

Opbouw	
Complexiteit	
Additionele feedback	

6 - Debriefing

Onderwerp	**Notities**
Teneo Care - Past binnen de lijn van Teneo Care	
Data opslaan en verwerken voor evaluatie	
Contact veranderen door dit product	
Beste aspecten product	
Missende functies	
Suggesties voor aanpassingen	
Product aanschaffen? - waarom wel / niet?	
Privacy issues - Obsessive monitoring	
Maximale prijs	
Additionele feedback / suggesties / commentaar	

Evaluation - face-to-face session (semi-structured)

Stakeholder: Informal caregiver

1 - Informatiebrochure en toestemmingsverklaring

Openingsstatement
'Onderzoek en conceptueel ontwerp van een nieuw user-driven valdetectiesysteem voor ouderen' *Bacheloropdracht Creative Technology 2020* *Carlijn Rendering, s1964437* *c.rendering@student.utwente.nl* *U wordt uitgenodigd om mee te doen aan een bachelor afstudeeronderzoek naar val-gerelateerde technologieën voor ouderen. Het doel van dit onderzoek is het ontwerpen van een conceptueel design voor een nieuw valdetectie product voor ouderen (70+). Het afstudeeronderzoek wordt uitgevoerd voor de opleiding Creative Technology in samenwerking met Teneo-IoT B.V.*

Toestemmingsverklaring
Wat wordt er van u verwacht? U neemt deel aan een semi-gestructureerde evaluatie sessie waarin aan u open en gesloten vragen zullen worden gesteld over het onderzoeksproject *conceptueel ontwerp van een 'nieuw user-driven valdetectiesysteem voor ouderen'*. De onderwerpen die besproken zullen worden zijn: polsband met valdetectiesysteem en smartphone app. Van het interview zal een audio- en video opname worden gemaakt, zodat het gesprek later ad-verbum (woord voor woord) kan worden uitgewerkt. Dit transcript wordt vervolgens gebruikt in het verdere onderzoek. Voordat de onderzoeksgegevens naar buiten gebracht worden, worden uw gegevens anoniem gemaakt. In een publicatie of presentatie zullen de anonieme gegevens worden gebruikt. U dient tenminste 16 jaar te zijn om deel te nemen aan dit onderzoek. **Vrijwilligheid** U doet vrijwillig en anoniem mee aan dit onderzoek. Daarom kunt u op elk moment tijdens het onderzoek uw deelname stopzetten en uw toestemming intrekken. **Wat gebeurt er met mijn gegevens?** De onderzoeksgegevens die in dit onderzoek verzameld worden, zullen enkel gebruikt worden voor dit onderzoek als informatieve methode om het probleem en het doelpubliek te begrijpen. De gegevens zullen anoniem gemaakt worden en blijven. Alle onderzoeksgegevens worden op beveiligde wijze volgens de richtlijnen van de Universiteit Twente bewaard.

Heeft u vragen/opmerkingen over het onderzoek?
Als u meer informatie over het onderzoek wilt, kunt u contact opnemen met Carlijn Rendering.

Telefoon: +31 6 30207706;
Adres: Beethovenstraat 20, 7131AK Lichtenvoorde
E-mail: c.rendering@student.utwente.nl

Voor meer informatie over Teneo-IoT B.V., bezoek de website: https://teneo-iot.nl/

Mocht u klachten hebben over dit onderzoek, dan kunt u deze richten aan de secretaris van de Commissie Ethiek van de Faculteit der Elektrotechniek, Wiskunde en Informatica van de Universiteit Twente, postbus 217, 7500 AE Enschede (NL), email: ethics-comm-ewi@utwente.nl).

Door te klikken op de knop **'Ik ga akkoord'** geeft u aan dat u de bovenstaande informatie heeft gelezen, vrijwillig meedoet aan het onderzoek en 18 jaar of ouder bent.

→ Versturen via mail

2 - Inleidende beschrijving afstudeeronderzoek

Mondelinge uitleg over afstudeerproject + afbeeldingen laten zien.

Uitleg bachelor afstudeeronderzoek

Deze bachelorscriptie richt zich op het ontwikkelen van een valdetectiesysteem voor ouderen. Dit valdetectiesysteem kan tevens de hartslag van de gebruiker monitoren en kan een alarm afgeven bij abnormale hartritmes en hartstilstand. Het systeem bestaat uit drie delen:

- Polsband met het valdetectiesysteem (voor de ouderen)
- Gekoppelde app voor de smartphone (voor de verzorgenden)
- Draadloze oplader (voor de polsband)

AFBEELDINGEN INVOEGEN

Polsband met valdetectiesysteem
De polsband kan detecteren of iemand gevallen is en kan tevens hartslag afwijkingen registreren en melden. Er zijn drie situaties mogelijk:
- de oudere heeft hulp nodig en kan zelf de alarmknop indrukken waardoor een alarm naar de app gezonden wordt
- de oudere is gevallen en er wordt automatisch een alarm gestuurd, tenzij de oudere binnen 10 seconden de alarmknop indrukt om het alarm niet te verzenden
- de polsband detecteert een abnormaal of geen hartritme, er wordt direct automatisch een pushbericht naar de app gestuurd.

Gekoppelde smartphone-app
Elke gebruiker van de polsband is middels de bijbehorende smartphone-app gekoppeld aan een groep van zorgverleners. Deze zorgverleners werken samen in de app. Binnen de groep is één persoon de 'admin' met speciale rechten/privileges en de rest zijn 'team members'. De activiteiten op de smartphone-app voor de 'admin' als 'team members' zullen bestaan uit bijvoorbeeld:

aangeven of de verzorgers momenteel beschikbaar zijn voor hulp of niet en het invoeren van bezoekafspraken met de oudere. De speciale activiteiten die alleen de 'admin' kan uitvoeren zijn bijvoorbeeld: het up-to-date houden van de lijst met verzorgers, het invoeren van de juiste volgorde waarin de verzorgers worden gewaarschuwd, instellen van de straal van de geofence (een gebied waarin de oudere zich kan begeven en waarbij een melding gegeven wordt als de oudere buiten dit gebied gaat), instellen welke services er gebruikt worden. Via de app kunnen de verzorgers met elkaar communiceren.

3 - Algemeen

Onderwerp	**Notities**
Leeftijd	
Tijd kwijt aan mantelzorgtaken, belangrijkste mantelzorgtaken	
Beschrijving conditie van persoon waar mantelzorg aan verleend wordt	
Ervaringen met traditionele noodknop	
Smartphonegebruik Gebruik van apps Technologie	

4 - Polsband met valdetectiesysteem

Laten zien van het ontwerp van de polsband en beschrijving ervan geven.

Onderwerp	**Notities**
'Look & feel' / ontwerp / design	
Opladen	
Interactie tijdens alarmsituatie	
Sluitingsmechanisme	
Stigmatisering	

5 - Smartphone-app

Inleidende uitleg geven over mock-up smartphone-app:

- Afhankelijk input data buitenaf → situaties handmatig stimuleren
- Nog niet alle interactie gerealiseerd → Alleen belangrijkste onderdelen
- Interactie komt niet altijd overeen met de interactie in daadwerkelijke smartphone-app

Vragen om 'screen-sharing' te activeren.

Opdrachten

Opdracht	**Notities**
Inloggen als admin	
Pairing	
Home dashboard	
Alarm sectie (alarm uit) - Aantal mensen toegang tot woning - Aantal mensen AED - Wie eerste gewaarschuwd - Hoeveel mensen in 'carers list' - Wie is niet beschikbaar	
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---5 minuten zelfstandig testen van de app---	

Onderwerpen voor evaluatie

Onderwerp	**Notities**
‘Onboarding’/introducerende tour/ingebouwde handleiding	
“Look & feel” / Design	
Kleurstelling	
Iconen	
Lettertype	
Opbouw	
Gebruiksvriendelijkheid	
Complexiteit	

6 - Debriefing

Onderwerp	**Notities**
Ontzorgen of juist meer zorgen	
Verandering in contact met oudere door dit product	
Beste aspecten product	
Missende functies	
Suggesties voor aanpassingen	
Product aanschaffen? - waarom wel / niet? - Vergelijking traditionele noodknop	
Privacy issues	
Maximale prijs	
Additionele feedback / suggesties / commentaar	

Afsluiting
Hartelijk dank voor uw deelname en tijd.

Appendix J Online questionnaire survey [Evaluation]

Evaluatie Teneo-IoT B.V.

*Vereist

Toestemmingsverklaring

1. Door te klikken op de knop 'Ik ga akkoord' geeft u aan dat u de bovenstaande informatie heeft gelezen, vrijwillig meedoet aan het onderzoek en 16 jaar of ouder bent. *

   Markeer slechts één ovaal.

   ◯ Ik ga akkoord *Ga naar sectie 4 (Uitleg Bacheloronderzoek)*

   ◯ Ik ga niet akkoord *Ga naar sectie 3 (Einde van enquête)*

Einde van enquête

U heeft de enquête verlaten. Hartelijk dank voor uw tijd.

Uitleg Bacheloronderzoek

Deze bachelorscriptie richt zich op het ontwikkelen van een valdetectiesysteem voor ouderen. Dit valdetectiesysteem kan tevens de hartslag van de gebruiker monitoren en kan een alarm afgeven bij abnormale hartritmes en hartstilstand. Het systeem bestaat uit drie delen:
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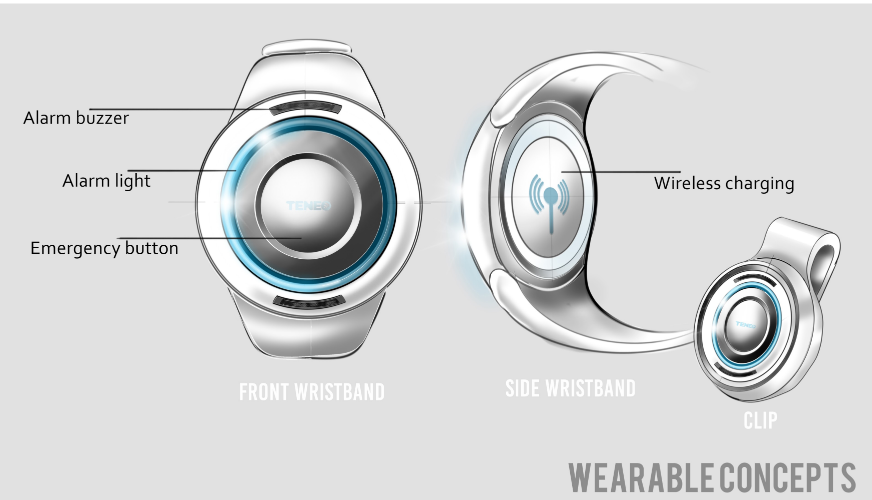
TENEO UNIVERSITY OF TWENTE.



Algemene vragen

2. In welke leeftijdscategorie valt u? *

Markeer slechts één ovaal.

- ( ) 18 - 25
- ( ) 26 - 35
- ( ) 35 - 45
- ( ) 45 -55
- ( ) 55 - 65

3. Wat is uw functie binnen het bedrijf?

____

4. Heeft u ervaring met mantelzorgen? *

Markeer slechts één ovaal.

- Ja, ik ben mantelzorger
- Ja, iemand in mijn directe omgeving is mantelzorger
- Nee

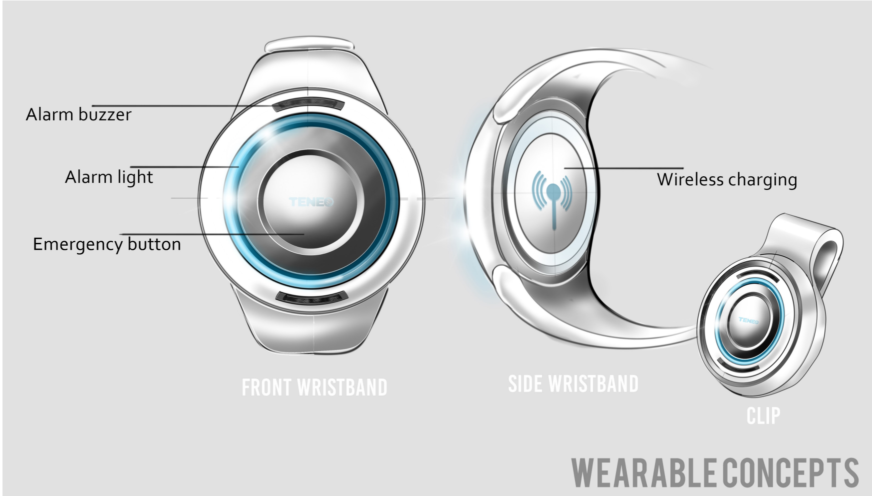
5. Aan welke minimale eisen zou volgens u dit product moeten voldoen? Noem de twee belangrijkste eisen. *

6. Wat maakt volgens u een valdetectie apparaat gebruiksvriendelijk? Noem de twee belangrijkste aspecten. *

Polsband met valdetectiesysteem

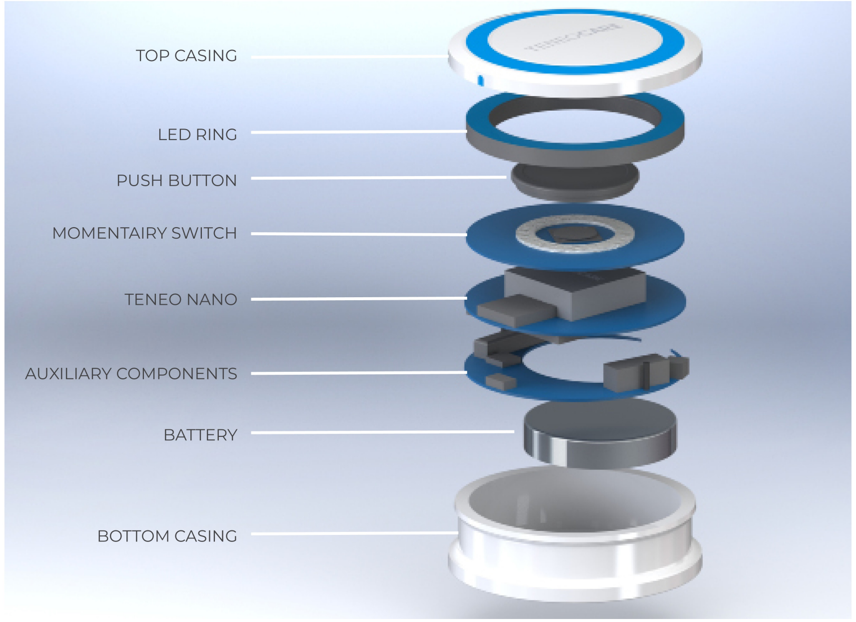
De vragen hieronder richten zich op de polsband met valdetectiesysteem.
Hieronder zijn verschillende afbeeldingen te zien van de polsband.

Ontwerp concept



Behuizing Teneo Care module

Exploded view - Teneo Care module



Modulaire opbouw

Tijdens het afstudeeronderzoek ontstond het idee om het product modulair op te bouwen. Het product bestaat hierbij uit een draagconstructie (polsband, halsketting, clip, etc.) en losse modules die in de draagconstructie bevestigd kunnen worden. Voorbeelden van deze losse modules kunnen zijn: valdetectiesysteem, fitness tracker, modules specifieke aandoeningen (MS, suikerziekte, etc.), slaap monitoring, etc.

7. Hoe beoordeelt u de technische haalbaarheid van deze modulaire opbouw waarbij de module zowel in een polsband, aan de broekriem of als halsketting gedragen kan worden (met software aangepast aan de methode van dragen)? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Technisch onhaalbaar	◯	◯	◯	◯	◯	◯	Technisch haalbaar

8. Opmerking over technische haalbaarheid

Alleen invullen als u aanvullende opmerkingen hierover heeft.

9. Hoe beoordeelt u de toegevoegde waarde van deze modulaire opbouw waarbij de module zowel in een polsband, aan de broekriem of als halsketting gedragen kan worden (met software aangepast aan de methode van dragen)? *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Geen toegevoegde waarde	◯	◯	◯	◯	◯	◯	Grote toegevoegde waarde

10. Opmerking over toegevoegde waarde

Alleen invullen als u aanvullende opmerkingen hierover heeft.

Stigmatisering

Het dragen van een (medisch) hulpmiddel voor ouderen wordt door ouderen vaak ervaren als stigmatiserend.

11. Denkt u dat ouderen zich gestigmatiseerd voelen als zij dit product dragen? Nee / Ja, omdat.... *

Smartphone-app

De vragen hieronder richten zich op de bijbehorende smartphone-app.

Testen van de smartphone-app

U zult nu het prototype (mock-up) van de smartphone-app testen. Het prototype van de app is gerealiseerd met de ontwerptool Adobe XD. Adobe XD is een vector-gebaseerd hulpmiddel voor UX/UI design en prototyping. De ontwerptool is bedoeld om het werkend testmodel van de app te delen met opdrachtgever voor feedback en vervolgens alle componenten te exporteren zodat een developer de uiteindelijke app kan bouwen.

Openen van de smartphone-app

Hieronder is de link te vinden naar het prototype van de app. U wordt gevraagd de app te openen in een nieuw tabblad en deze vragenlijst in het huidige tabblad open te laten staan, zodat u het prototype kunt testen en ondertussen verder kunt gaan met deze vragenlijst.

Link: https://xd.adobe.com/view/16e06fdf-1af6-4157-5bb7-8bcdda53f7ff-60d1/
Wachtwoord: GP-Carlijn1

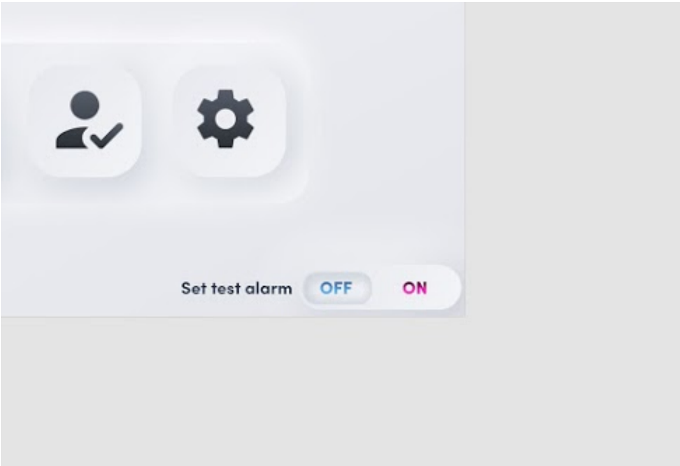
Opmerkingen vooraf

De taal gebruikt in de app is Engels.

De werking van de app is voor een groot deel afhankelijk van data die doorgestuurd wordt van de polsband naar de app, bijvoorbeeld bij een alarmsituatie. Bij dit prototype is er nog geen verbinding gemaakt tussen de polsband en app, met als gevolg dat er geen data doorgestuurd wordt. Wel kunnen verschillende situaties die afhankelijk zijn van data van buitenaf gestimuleerd worden door ze handmatig in te schakelen. Een voorbeeld hiervan is de alarmsituatie. Deze kunt u uitproberen door de switch om te zetten (zie afbeelding hieronder).

Verder is het belangrijk vooraf te vermelden dat nog niet alle interactie mogelijk is en dat sommige schermen nog statisch zijn. Het prototype is vooral bedoeld om een indruk te geven van wat er allemaal mogelijk is.

Switch om alarmsituatie te stimuleren



Instructie 1

Open de app en kies als gebruiksmodus (user-mode) 'Admin'.

12. Wat is de eerste handeling die u als 'Admin' uitvoert na de 'verification'? *

____

Instructie 2

Ga nu naar het 'Home Dashboard'.

13. Na hoeveel keer 'klikken' bent u op het 'Home Dashboard'? *

____

Instructie 3

In de app heeft u als gebruikersnaam 'TestUser'. Onderstaande vragen hebben betrekking op het begrijpen van de 'verzorgers-lijst'.

14. Als hoeveelste verzorgende zult u gewaarschuwd worden in geval van alarm? *

Markeer slechts één ovaal.

- ◯ Eerste persoon
- ◯ Tweede persoon
- ◯ Derde persoon
- ◯ Vierde persoon
- ◯ Vijfde persoon
- ◯ Zesde persoon

15. Wie zal als vierde gebruiker gewaarschuwd worden? *

____

16. Hoeveel gebruikers hebben een AED tot hun beschikking? *

AED = Een draagbaar toestel dat wordt gebruikt bij de reanimatie van een persoon met een hartstilstand.

Markeer slechts één ovaal.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6

17. Welke gebruiker is vandaag niet beschikbaar? *

18. Hoeveel gebruikers hebben toegang tot het huis van de oudere (polsband drager)? *

Markeer slechts één ovaal.

- 1
- 2
- 3
- 4
- 5
- 6

Instructie 4

Test nu de alarmsituatie door de switch onderin het 'Home Dashboard' om te zetten.

19. Welk type alarm is geactiveerd in deze situatie? *

Markeer slechts één ovaal.

- Emergency push alarm
- Automatic alarm
- Personal alarm

Instructie 5

Geef nu aan dat u beschikbaar bent om hulp te verlenen.

Bekijk daarna de locatie van de oudere (polsband drager) op de kaart.

20. Hoe vaak moest u in totaal 'klikken' voor deze twee handelingen? *

Instructie 6

U heeft gebeld met de oudere en het bleek loos alarm te zijn. Reset het alarm.

21. Hoe vaak moest u in totaal 'klikken' om het alarm te resetten? *

Instructie 7

Activeer nogmaals de alarmsituatie door de switch onderin het 'Home Dashboard' om te zetten. Geef nu aan dat u NIET beschikbaar bent om hulp te verlenen.

22. Beschrijf wat er gebeurt in de app. *

Instructie 8

Ga terug naar het 'Home Dashboard' en vanuit daar naar screen 'Admin Rights'.

23. Hoe vaak moest u in totaal 'klikken' om het scherm 'Admin Rights' te bereiken? *

24. Welke dingen kunt u in 'Admin Rights' invullen en wijzigen? *

Instructie 9

Ga terug naar het 'Home Dashboard' en vanuit daar naar screen 'Geofencing'.

25. Wat is de maximale grootte die u kunt instellen bij het geofence in dit prototype? *

Geofence = Een soort virtueel hek. Bij overschrijden van het virtuele hekwerk door de oudere (polsband drager) zal er een bericht verzonden worden.

____

Instructie 10

Klik nu op het 'Home' icoon onder het prototype van de app (zie afbeelding) en log nu in als 'Member'.

Instructie 11

Controleer de 'Battery status'.

26. Hoeveel tijd resteert om de batterij op te laden? *

____

Instructie 12

Gebruik nu 5 minuten om de functionaliteit van het prototype van de app op eigen gelegenheid te testen. Voorbeelden van dingen die u kunt testen: medische gegevens bekijken, afspraak plannen in de agenda, uitvoeren van een chat of controleren of de polsband gedragen wordt door de oudere.

27. Noteer uw op- en aanmerkingen tijdens het zelfstandig testen hier.

____

____

____

____

____

Rating vragen smartphone-app

Hieronder volgen een aantal 'rating-vragen'. Graag per stelling aangeven in welke mate u het eens bent met de stelling (1=totaal mee oneens, 6=totaal mee eens). Daarnaast is er mogelijkheid om per stelling een opmerking te geven. Het is niet verplicht om bij elke stelling een opmerking toe te voegen.

28. STELLING: Het kleurgebruik in de app past bij de branding van Teneo-IoT. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

29. STELLING: De kleurstelling van het alarm past bij de functie. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

30. STELLING: De kleurstelling van de app draagt bij aan een minimale cognitieve belasting. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

31. Opmerkingen en/of aanvullingen stellingen 'kleurgebruik'

32. STELLING: De “look & feel” van de app sluit aan bij de doelgroep (mantelzorgers, meestal 50+). *

In softwareontwerp is "look & feel" een term die wordt gebruikt met betrekking tot een grafische gebruikersinterface: vormgeving (look) en de interactieve stijl (feel).

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Totaal mee eens

33. Opmerkingen en/of aanvullingen stelling 'look & feel'

34. STELLING: De gebruikte iconen zijn intuïtief en duidelijk. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Totaal mee eens

35. Opmerkingen en/of aanvullingen stelling 'iconen'

36. STELLING: Het lettertype is goed leesbaar. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Totaal mee eens

37. Opmerkingen en/of aanvullingen stelling 'lettertype'

38. STELLING: De opbouw van de app is overzichtelijk en toegankelijk. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Totaal mee eens

39. Opmerkingen en/of aanvullingen stelling 'overzicht en toegankelijkheid'

40. STELLING: De app is onnodig complex. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

41. Opmerkingen en/of aanvullingen stelling 'complexiteit'

42. STELLING: Het product heeft meerwaarde ten opzichte van een traditionele noodknop. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

43. Opmerkingen en/of aanvullingen stelling 'meerwaarde traditionele noodknop'

44. STELLING: Er is teveel inconsistentie in de app. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

45. Opmerkingen en/of aanvullingen stelling 'inconsistentie'

46. STELLING: De app is makkelijk in gebruik. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

47. Opmerkingen en/of aanvullingen stelling 'gebruiksvriendelijkheid'

48. STELLING: Ik mis een 'onboarding'/introducerende tour/ingebouwde handleiding *

Onboarding is een term voor een proces gericht op nieuwe klanten die het midden vindt tussen een persoonlijk warm welkom en het wegwijs maken in de aangeschafte diensten en producten.

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

49. Opmerkingen en/of aanvullingen stelling 'onboarding'

50. STELLING: Het is eenvoudig om persoonlijke aanpassingen te verrichten binnen de app. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	◯	◯	◯	◯	◯	◯	Totaal mee eens

51. Opmerkingen en/of aanvullingen stelling 'persoonlijke aanpassingen'

52. STELLING: Het logo van het product (scherm 4/75 in prototype) sluit aan bij de branding van Teneo-IoT en binnen de lijn van gezondheidshulpmiddelen. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Totaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Totaal mee eens

53. Opmerkingen en/of aanvullingen stelling 'logo Teneo Care'

Vragen over totale product

54. Denkt u dat door dit product het persoonlijk contact met de oudere zal veranderen?Ja / nee, waarom..... *

55. Denkt u dat de gegevens over het (bijna) vallen van een patiënt moeten worden opgeslagen voor evaluatie onderzoek, bijvoorbeeld voor fysiotherapeuten? Ja / nee, waarom.... *

56. STELLING: De privacy van de oudere (polsband drager) wordt teveel beperkt door dit product. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Helemaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Helemaal mee eens

57. Opmerkingen en/of aanvullingen stelling 'privacy'

58. STELLING: Door dit product is er kans op obsessief controleren en in de gate houden van de oudere (polsband drager) door de verzorgenden. *

Markeer slechts één ovaal.

	1	2	3	4	5	6	
Helemaal mee oneens	⬭	⬭	⬭	⬭	⬭	⬭	Helemaal mee eens

59. Opmerkingen en/of aanvullingen stelling 'obsessieve controle'

Debriefing

Onderstaande vragen kunt u beantwoorden nadat u de app gesloten heeft.

60. Welke functies mist u in de app? *

61. Vond u iets frustrerend en zou u dat graag eenvoudiger of anders willen zien? *

62. Wat vindt u het beste aspect aan het product? *

63. Hoeveel zou u voor dit product willen betalen als u het zelf nodig zou hebben?

Markeer slechts één ovaal.

- €200 - €300
- €300 - €400
- €400 - €500
- Meer dan €500

64. Wat komt er bij u het eerst naar boven als u denkt aan het product (hoe zou u het voor een vriend beschrijven?) ? *

65. Heeft u additionele feedback, suggesties of commentaar die niet aan bod zijn gekomen in de enquête waarmee u mij kunt helpen bij dit onderzoek? *

Einde enquête

Hartelijk dank voor uw deelname en tijd.

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