arhealth

Enabling wellness as a road to health with service design.

TU Delft

Arçelik

arhealth: Enabling wellness as a road to health with service design

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Acknowledgements

As the icon of this project is a heart, my heart goes out to all the people that helped me in my graduation path and without whom I would not be here.

To my family, that have always given me the support I needed to fight for my dreams and take risks. I hope to be with you again soon, with my mom and dad in Mexico and my sister in Madrid.

To my other family, my Mexican roommates of number 17, thank you for being there when It counted the most, thank you for the funny moments during the sleepless nights and for being my guinea pigs when I needed test subjects.

To Tony and Korkut from Arçelik, thank you for believing in me and inviting me to a project that allowed me to explore the field almost boundless. Tony, I will miss our weekly update meetings a lot.

To my supervisory team at TU, Peter and Lianne, thank you for the support and encouragement, especially when things were tough, I know I was an email away from help.

To the brilliant minds and souls that I have met at TU and the support you gave me during the way, and to my IDE Academy family: Ianus, Ehsan, Charlotte, Priyanka and Gabriele.

Abstract

The COVID-19 health crisis at the beginning of 2020 saw a dramatic number of adaptations to health systems around the world. One of these adaptations was the accelerated shift towards e-health solution. This rise happened because of the inability of the medical system to serve patients of non-respiratory related illnesses during the pandemic. This was experienced as a rise from 1% to 70% of remote general practitioners consultations in the early months of 20201.

Key to these consultations is the use of medical devices to gather information relating to the patient's state. New medical device categories now allow people with little or no training to collect accurate information[2], including by using wearables first intended for tracking activity-related metrics that are currently being fitted with state-of-the-art sensors that allow them to become a realistic alternative to strict medical devices[3]. Despite this, several key issues impede their use in standard medical practice and are more commonly used as informational tools only[3].

The use of wearables as informational tools has the potential to increase the awareness of people of the effect of the things they do on their wellbeing, an essential part of the concept of preventative medicine. A concept that aims to enhance wellbeing is wellness, with health being a state of being and a goal to achieve[4].

Wellness is also a concept that is well entrenched on the product lines of the brands of Arçelik, and is seen as an important opportunity to grow medical capabilities in the products they already dominate.

This thesis project presents a service design concept that aims to help people create their own wellness journey by passively tracking habits and receiving advice based on this information. The concept is based around the gathering of information through smart home appliances, focused around four modules: nutrition, activity, sleep and vitals.

The project concludes that the proposed service solution brings the possibility to integrate the capabilities that Arçelik needs to enter the larger healthcare market while staying in the product categories that it dominates.

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Chapter 1:

Introduction

1 Project Introduction

1.1 Background and setting

The COVID-19 health crisis at the beginning of 2020 saw a dramatic number of adaptations to health systems around the world. One of these adaptations was the accelerated shift towards e-health solutions, happening as healthcare systems struggled with a rising number of patients and the inability to serve them in a hospital setting [5]. An example of this shift can be seen in the United Kingdom, where before the pandemic, less than 1% of consultations with general practitioners were remote. Still, by April of 2020, an estimated 70% of them were remote[1].

This adoption has been successful because two important barriers were crossed: compliance with legislation and a shift in patient attitude. The first one was achieved as traditional health systems worldwide were put on the brink of collapse, and remote consultations were quickly allowed to operate as a viable alternative to stop people from traveling to hospitals to receive medical care [5]. In order to enable them to operate, certain laws and regulations were either relaxed or revised, such as those that would allow for e-health to be subsidized by insurance [6]. The second reason relates to the change in the attitude of patients toward e-health changed, as consultations in person were no longer possible. Practices quickly adapted to a new remote setting, and this attitude changed from one of "the doctor must not think my problem is important since he gave me an e-health appointment" to "the doctor cares about me and therefore is seeing me via e-health" [7].

Currently, these alternatives for in-person care are expressed as systems that replace visits with an interface that offers the possibility of a video or audio consultation. Some of these systems also provide advanced features like prescription management or medical history sharing in a single software solution, integrating with existing EHR (Electronic Health Record) systems.

1.2 The problem

Attitudes and regulations became friendlier towards the widespread use of e-health and are likely to stay positive even when the COVID-19 crisis ends [8]. However, the practical issues of shifting to digital product-service systems that facilitate care from practitioners to patients still represent a problem to widespread adoption [7]. These practical issues represent technical barriers, system barriers, and personnel-related barriers.

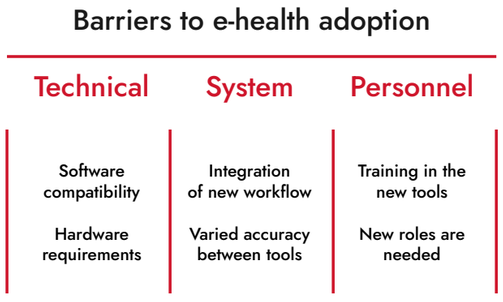


Figure 1. Barriers to the adoption of e-health.

The product-service systems that are being adopted result from a design process that focuses on the continuation of in-person services, with most of those solutions built on assumptions established well before the pandemic started and do not account for the new opportunities that it has created [9]. Because of this, they are bound by the same limitations of existing in-person services, without exploring the newly expanded limits of the field and a new attitude of patients toward solutions that blur the line between lifestyle and medicine. As explained in the introduction of the project, most e-health solutions catered to establishing medical contact between practitioners and patients are medical Zoom-like platforms that limit patients and practitioners to a rectangular screen.

Medicine is not about disease; it is about people. How can the use of design practices allow for a new proposal of integrated e-health services aimed at making healthcare user-centered and enhance the experience that is currently offered?

1.3 Assignment

Deliver an actionable design vision for Arçelik for their entry into the e-health market with a service solution that builds upon the new possibilities opened by the recent pandemic and their own experience in creating product-service systems.

1.4 The client: Arçelik

This project is carried out by Arçelik, a Turkish multi-national household appliances manufacturer based in Istanbul established in 1955. The company owns 12 brands and has offices in 32 key international markets, including production facilities in 7 countries serving a further 145 countries.

White goods represents the biggest market in which Arçelik has a presence in 10. This market grew 4% in 2020 despite the global pandemic, and was instead characterized by dramatic changes in many aspects of consumer behaviors. Arçelik possesses the second largest share of the household

Figure 2. Arçelik markets their products under their brand in Turkey, while in Europe they are present mostly as Beko and Grundig.

appliance market in Europe 10, mostly with Beko and Grundig. Beko is also the leader of the Europe freestanding white goods market, and in the UK and Poland in the white goods market.

With this project, Arçelik is evaluating the opportunity to enter into a new market with a value proposition that integrates their experience with creating product-service systems that serve the everyday needs of people.

1.5 Approach and methodology

The project aimed to deliver a design vision in the form of an e-health service concept as a stepping stone for Arçelik to enter the healthcare market.

This thesis project was divided into four general phases and follow the method known as the Double Design Diamond. Through these four phases, different tools were used to perform the main objective of the phase and are described below.

Discover

The first phase had as an objective to under understand the rapidly changing context of primary healthcare in the post-COVID19 world, identifying the current problems and opportunities. Besides a desk research phase, user research was done to contextualize the issues further into the Netherlands and get a more personal understanding of the situation. This user research is explained in a Journey Map, a tool meant to convey the journey of a user through a service, showing the interactions and the parts of the service that work and those that might need improving.

Define

The define phase aims to establish the basis for the strategic implications of a new strategy for Arçelik, joining the insights of the discover phase with the current technological developments and the brand values. A deep look at the company was taken, as well as their past developments in the area of healthcare. This research allowed the project to be scoped down from the area of health in general to that of wellness and establishes this concept as the basis for the strategy of this project.

For this purpose, tools from the Design Roadmapping process were followed to deliver a strategy for Arçelik in the field of healthcare. The application of these tools started with a technology scouting and trend analysis, ending with a future vision.

Right on the edge of the define and develop phases, a service design brief was developed. This brief allowed the system to be delimited to a reduced number of opportunities and cleared the way for a focused application of the tools of service design.

Develop

This phase started with ideation sessions with stakeholders of Arçelik and users of healthcare services, and owners of home appliances. During these sessions, journey maps were again used to establish user stories, detect pain points and explore opportunities. Following these ideation sessions, the developed concepts were dissected and explored, ending with the development of two concepts that were later merged into one: arhealth.

The tools used in this phase were service blueprinting with scenarios and experience prototyping, both intended to convey the concept to a validating audience. This validation was done with stakeholders of Arçelik in an interactive session and from users in a process that followed them through the use of mockups of the service solution.

Deliver

The insights from the validation session were analyzed, and changes to the service concept were proposed. Ultimately, the service is delivered in a roadmap and user scenarios. From these tools, a final validation session with Arçelik was done, gathering a final impression of the project at a stakeholder level.

In this last phase, the final personal evaluation of the project takes shape as well. Allowing to reflect on the results and shortcomings of the project, paving the way for future development and serving the author's development objectives.

Figure 3. Visualized design process.

Chapter 2:

The changing landscape of healthcare

2 The changing landscape of healthcare

When talking about healthcare in a modern context, e-health is a term that needs to be understood. This chapter will start with the definition of e-health, its promise, and the application of e-health in the context of COVID-19 and at home consultation aided by IoT medical devices.

2.1 E-health

The World Health Organization defines e-health as the use of information and communication technologies (ICT) for health[11]. While e-health is at the forefront of technologies that aim to digitize medicine, it is also a term that is used to encompass a series of technologies upon which medicine has only recently begun to lean in to. So, while e-health is the means through which patients and practitioners come together, and is composed of the technologies that facilitate such connection, it is also is invariably linked to those that facilitate the process of medical analysis.

2.1.1 The promise of e-health.

While e-health has at times been called a miracle cure for all the problems of all health systems around the world, there is a dissenting opinion that the mechanization of medicine is not in the interest of the practice[12]. This mechanization, however, did not start with e-health. The main advance in the workflow of medicine that changed it forever was the introduction of the HER, a tool that was mainly meant to help with billing and insurance claims, but has become an intruder in the relationship of doctors with patients [3].

It is now a prevailing opinion that one of the first advantages of a widespread e-health adoption is that it will allow doctors to automate mechanical tasks and allow them to devote more time to patients [14]. In his book "Deep Medicine", Eric Topol describes this opportunity as that of "heightened humaneness—with more time together, compassion, and tenderness—to make the "care" in healthcare real. To restore and promote care."[14]

2.1.2 E-health in the COVID-19 context

Because of the remote nature of the systems applied during the pandemic to stop the spread of the virus, they fall under the category of e-health and mobile e-health. As shown in Figure 5, this increase in adoption can be roughly divided in two categories: Disease related applications and actions to reduce pressure on health systems. Both actions were also typically led by a triage that determined the appropriate case, seeking to quickly evaluate the risk of a patient of both contracting and already carrying the disease.

The first category is dedicated to those e-health actions directly related to the disease. The application of a triage service by phone was a service that was replicated around the world, as many public health systems already had a framework for this system[15]. As testing services and contact tracing were also rolled out, they were integrated as part of this triage system intended to keep the possibly infected

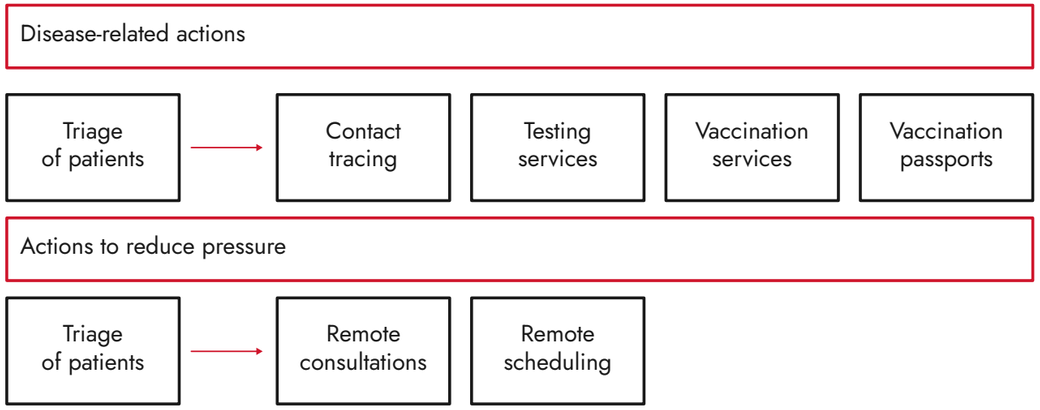


Figure 4. Application of e-health solutions during the COVID-19 pandemic.

out of hospitals and allowing for public health institutes to have a better strategic outlook on the advances of the disease and to anticipate needs. By early 2021 this system has also been used to rollout vaccinations and to form the basis for vaccination passports[16].

In the second category, the shift towards remote consultations is the most visible case. However, a series of ancillary services also saw a shift to remote or semi-remote settings. An example of this is standard laboratory services, that saw increased reliance on remote scheduling in order to keep working safely. Overall, this reliance on remote services was a trend in the medical sector as a whole. Despite this, not all consultations were replaced by remote consultations, as some patients chose to delay treatment or visits due to the pandemic[17].

2.2 COVID-19 as a catalyst for change

In late 2019 a new strain of the SARS-COV virus was first detected around the world as cases of coronavirus-related pneumonia[18]. By early 2020, the novel virus COVID-19 was identified as the culprit and governments around the world began to take measures to control the spread of the virus. In Europe, most countries had a form of lockdown in place by March 2020.

This strain of the virus was special because a typical flu virus has usually a balance between spread and mortality, with common flu having a high spread but a low mortality overall. This stems from the logic that a virus with a high mortality tends to extinguish itself quickly as hosts become unable to keep spreading it. But sometimes, as was the case in the previous SARS-CoV epidemic, a virus with both a high spread and a high mortality finds its way out onto the general population.

2.2.1 Effect on healthcare systems around the world

As the number of infected patients grew, the capacity of hospitals to deal with them quickly reached its limit. New measurements were put into place, that depending on the country, attempted to stop patients with low to mild symptoms to go to hospitals and instead asked them to stay home to stop the spread of the disease. This measurements were in line with those applied during other recent pandemics, as healthcare workers become important vectors of infectious diseases[19].

As hospitals closed, this also had an effect on the treatment of people not diagnosed with COVID-19 and increased the overall mortality of other diseases, especially chronic ones that until that point had relied on a constant access to in-person medical treatment. In addition, long-standing systemic health and social inequities proved to be an increased

factor of risk in getting sick from COVID-19 [20], as they prevent people from accessing healthcare at key moments during the advance of the disease.

2.2.2 A thin supply chain

Another effect of the pandemic was a new clarity towards the reliance of healthcare systems on worldwide supply chains. The hoarding of house products like toilet paper or spaghetti became a joke on social media, but the same happened with personal protective equipment (PPE) and medical equipment around the world[21]. From masks to ventilators, their prices rose amid heavy speculation on the possibilities of important disruptions on raw material supply chains and the rise in the need of ventilators for patients[22]. This shortage led to two important developments: the rise of independent efforts to design and manufacture medical equipment, and the intervention of the government to influence local manufacture.

The first development was primarily focused on producing ventilators, as early in the pandemic it was expected they would become a key tool to increase survivability in critically ill patients[23]. Many teams around the world started to work on new iterations of the mechanic ventilator that is used when people cannot breathe on their own. These teams, led by government entities, private companies, universities and even private individuals, aimed to innovate into a field largely controlled by a few major manufacturers. Most of the teams were focused on developing automated contraptions to the Bag-valve-mask (BVM)[24] that allowed it to be used without a human performing the pumping action. By early 2021 the EUA (Emergency Use Authorization) list of the FDA (Federal Drug Administration) currently mentions 86 approved ventilators[25] from medical device manufacturers such as Philips, startups like The Ventilator Project, and research groups like the University of Minnesota.

As the shortage of PPE became clear, governments took extraordinary measures to guarantee their supply. An example of this are medical-grade masks, of which about 50% of the worldwide supply was manufactured in China until their exports were halted[21]. This led to countries to excerpt pressure on local productions in order to increase, and in some cases to shift towards, the production of PPE. In Europe, industry organizations rallied to the call of the European Commission and estimated that thanks to these efforts they would be able to produce 1.5 billion surgical masks per month[26], a 20-fold increase from previous capacity.

2.2.3 Effect of comorbidity in mortality rate

As the disease first spread through the world, it became clear that a high number of patients suffering from it would need medical attention in a hospital in order to survive. The number was estimated to be up to 20%, and with the speed of the spread still being unknown, it led to grim expectations of overflowed hospitals[27]. The effect was expected to be felt not only in patients with COVID-19, but also by patients that would visit the hospital for other diseases that could be treated on a normal day, but because of the beds being already filled with patients, will have to be sent home.

As statistics were beginning to be compiled, another streak of data surprised investigators: the effect that other diseases in the patient had on overall mortality. Respiratory ailments, like asthma, were expected to play a role like they do in seasonal flu. But other seemingly unrelated ailments, like diabetes and hypertension, were discovered to play an important role and increase the possibility of complications in treatment that would result in a more-than-average entry rate to ICUs and overall mortality. This increase was later confirmed by the CDC, with 90% of hospitalized patients in the United States having one of five underlying conditions[28] as shown on Figure 6. These numbers are relevant, because excluding certain genetic predispositions, these diseases are

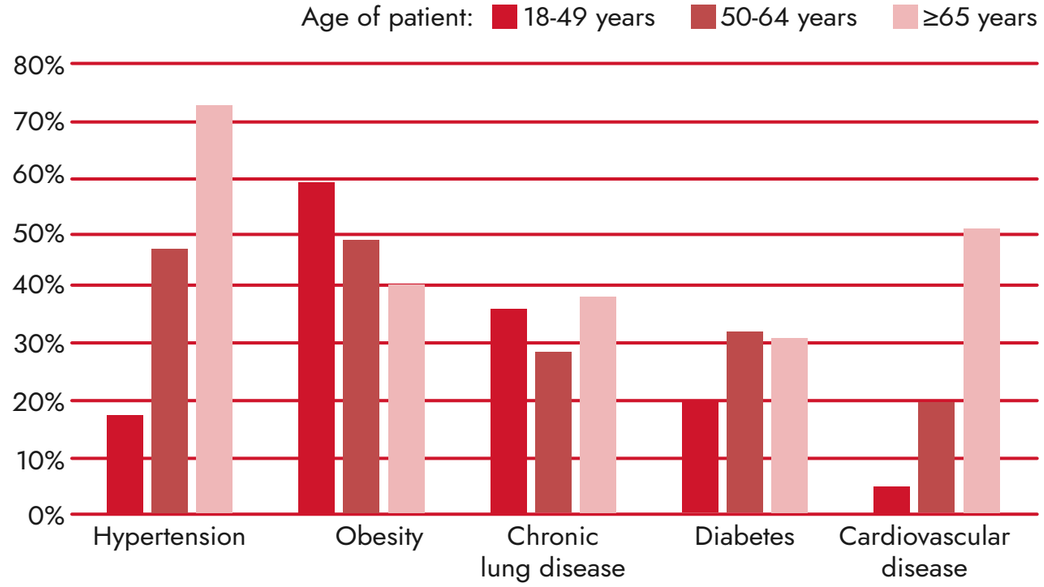


Figure 5. Underlying conditions among adults hospitalized with COVID-19, information from the CDC and adapted from Morbidity and Mortality Weekly Report (MMWR) March 1-30 2020.

commonly seen as preventable with diet and lifestyle changes[29].

This brought a paradoxical situation to healthcare systems worldwide. Without access to preventative healthcare, patients with these diseases would lack the means to control them, leading to more cases of complications if they were to become infected with COVID-19. But because of patients already suffering from complications from COVID-19, hospitals and other traditional means of having access to patients were limited.

2.3 Medical devices and regulations

According to the WHO, a medical device is "An article, instrument, apparatus or machine that is used in the prevention, diagnosis or treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose.". Under this very wide definition, a number of different classifications of medical devices exist and are primarily designed for regulation purposes[30]. In the United States, the FDA groups devices into 19 different medical specialties or panels, followed by product description and codes that determine which of the three categories, or classes, of regulatory controls the device is required to submit. Similar to this system, the Medical Device Directives (MDD) govern the classification of medical devices and are arranged according to the risk the device brings to the patient. While the process is extremely different between both regulatory processes, the result of both is expressed in the same manner: with a classification based on classes. This can lead to confusion as both systems are different in certain key characteristics.

2.3.1 MDD regulations

The European Commission sets the status of medical devices in the European directives AIMDD 90/385/EEC, MDD 93/42/EEC and IVDMDD 98/79/EC. When a device follows those directives, it is awarded a CE mark that allows it to be commercialized in the European Union as well as other territories that recognize it. The marking process varies according to the class of the device, with its determination being based on the risk it brings to patients and is shown in Figure7 [31]:

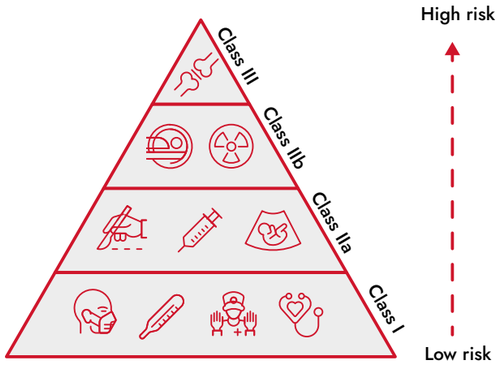


Figure 6. The four classes of medical devices of the European MDD framework, adapted from Strålin M. (2020) [31]

1. Class I medical devices: They have the lowest perceived risks to patients. Products under these categories that are not sterile or measuring can be self-certified, and example of this are corrective glasses. Products that are sterile or measuring devices like a stethoscope require a Notified body assessment from an MMD designated organization.

2. Class IIa medical devices: They constitute a low to medium risks to patients, and are designed to be used for a short-term period of less than 30 days. Examples of this category are surgical gloves and diagnostic ultrasound machines. In order to be approved, they require a Notified body assessment.

3. Class IIb medical devices: They constitute a medium to high risk to patients, and they might be used for a period of longer than 30 days. Examples of this category are surgical lasers and defibrillators. In order to be approved, they require a Notified body assessment.

4. Class II medical devices: These devices constitute the highest possible risk to patients and permanent monitoring is required during their lifetime. Examples of this category are hip-joint implants and cardiovascular catheters. In order to be approved, they require a Notified body assessment with additional audits on the technical documentation and quality inspections.

2.3.2 FDA regulations

The FDA in the United States classifies 1,700 generic types of devices into 16 medical specialties referred to as panels, with each device receiving a regulatory class depending on the level of control necessary to ensure the safety and effectiveness of the device. The class of the device determines the type of application that is necessary to gain approval, and depends on the intended use of the device and its indications of use, with those two factors being expressed in an expected risk[32].

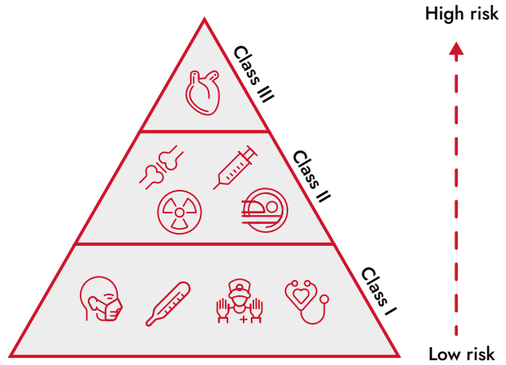


Figure 7. The three classes of medical devices of the FDA framework,, adapted from Strålin M. (2020) [31]

1. Class I medical devices: They have a low perceived risk and are rarely critical to life-sustaining care. They require only a Premarket Notification without clinical trials to be commercialized, with some types exempt from this requirement. Examples of this category are bandages or an electric toothbrush.

2. Class II medical devices: They constitute a moderate risk and are more likely to come into sustained contact with a patient. The FDA defines Class II devices as "devices for which general controls are insufficient to provide reasonable assurance of the safety and effectiveness of the device". Up to 75% of medical devices in this category undergo some form of clinical trials before being commercialized[33], with the rest being exempted if they can prove a substantial similarity to an already approved product. Examples of this category are contact lenses and syringes.

3. Class II medical devices: They constitute a high risk and are defined by the FDA as products used to "sustain or support life, are implanted or present a potential unreasonable risk of illness or injury". Class III devices require extensive clinical trials, unless they are not substantially different from an already-marketed Class III device. Examples of this category are pacemakers and defibrillators.

2.3.3 Differences between systems

While both systems classify risk in a very similar manner, due to the differences in the classification process, the same product can end up being classified in a different category in both systems. The root of this difference is that the MMD system uses a risk expectation based on a process that takes into account the duration of use, extent of contact with the body and whether they use an external power source, while the FDA uses the intended use of the device and its indications of use as its main source of information. This is also complicated if the product does not count with a similar already approved equivalent, called a predicate, and needs clinical trials to show safety and efficacy that can see it being bumped to a higher risk category[33].

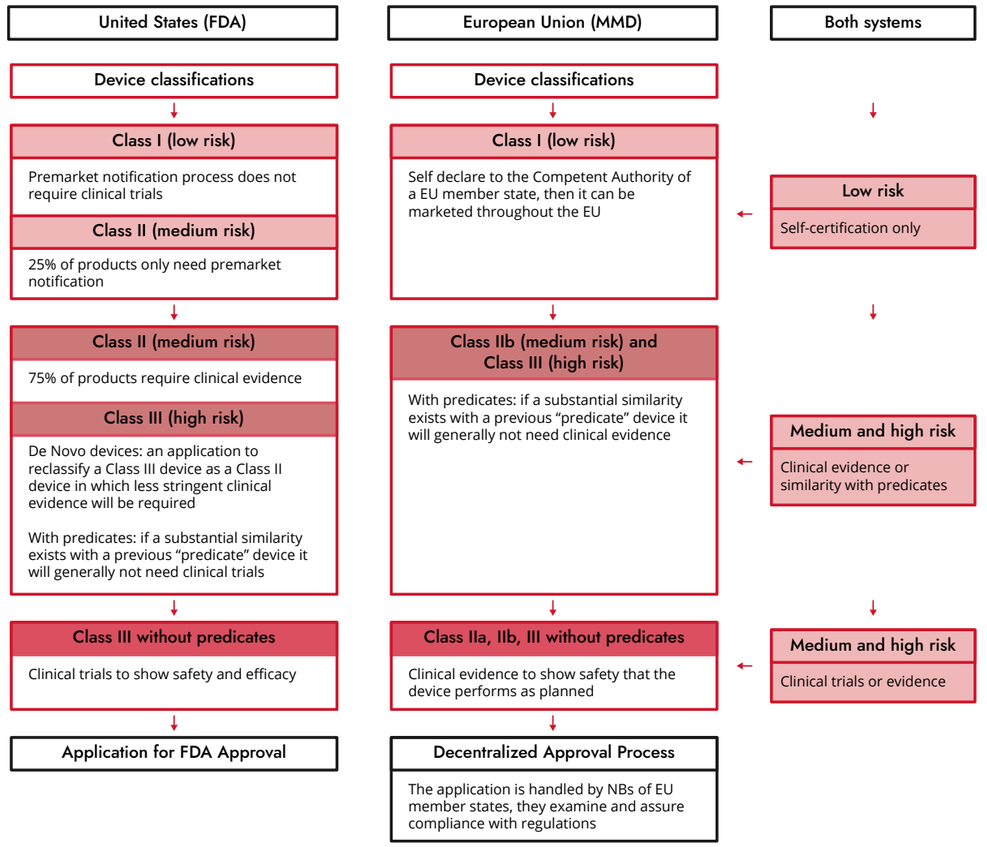


Figure 8. Overview of the approval process of medical devices in the United States and the European Union, adapted from Van Norman, (2016)[33]

Another important difference is that the CE mark is given to products that comply with applicable legislation and demonstrate to be safe and that they perform, or will probably perform, as designed with the potential benefits outweighing the potential risks, but without needing to show clinical efficacy[33]. This is in stark contrast to the FDA approval process that requires that a device must not only be safe but efficacious[34]. This stems from the founding objective of the FDA that was to regulate the marketing of medical products[35], while the MMD system was created to foster innovation and commercial policies and not as a public health or consumer protection agency.

Both systems have important strengths and weaknesses, with process of approval for a new device continuing to be a long, arduous and expensive path to take. The difference on this systems, however, means that some devices benefit from a faster path towards compliance in Europe and can save between 1 to 3 years due to the null requirement of showing efficacy[36]. This potentially faster path to approval has led to American companies seeking approval in Europe before submitting their application to the FDA.

2.3.4 Wearables and its legal status

While medical devices are closely regulated, there is still no legal definition of wearables or other non-traditional devices. Even as more devices of various categories are integrating medical measurement capabilities, they tend to fall into the generic list. A proposal by the European Commission in 2017 seeks to eventually define wearables as "body-borne computational and sensory devices which can sense the person who wears them and/or their environment. Wearables can communicate either directly through embedded wireless connectivity or through another device (e.g., a smartphone). Smart wearables may have control, communication, storage and actuation capabilities".

Without a definition for wearables and other non-traditional devices, it is also unclear in which cases they are bound by medical device rules. The key to solving this question in a per-case basis rests in what the Medical Devices Regulation 2017/745 (MDR) defines as "intended by the manufacturer to be used for specific purposes"[37]. Under this regulation, a device that is intended to be used as a source of health information for medical purposes would likely fall under such rules, while a device that gathers the same health information but does so for informational purposes would not.

2.4 IoT medical devices

With the declining in cost of networking capabilities, many IoT medical devices have been developed and the market is seeing a growth of over 19% every year[38]. Some of those devices are developed by manufacturers with experience in the healthcare sector and are simplified versions of devices used by hospitals, while others are innovations meant to miniaturize medical devices.

In order to get a better view of the market of IoT-capable medical devices, their manufacturers were categorized in three groups according to the intent of their devices. This analysis is meant to provide a clearer picture of the IoT device market inside the broad healthcare market, but because the definition of this overlap varies according to the source a new definition was constructed to scope this analysis:

An IoT medical device is a device that is capable of connecting to the internet or other devices and has the capability of recording medically accurate information about people without the need of special training

This definition has three key filtering characteristics:

1. The device can connect to the internet, an obvious and minimum requirement of IoT, but can also fulfill it if the device connects to another device before actually connecting to the internet.
2. The device is capable of recording medically accurate information, yet the intended use of this information can be other than a medical one.
3. The device is able to be used by non-trained or lightly trained people outside of a medical setup, while on some devices this requirement is clear, on others is more blurred as the use might be so specific that it is not expected to be used outside of a medical setup.

For the selection of the companies, no comparable information was found on the topic of specific market share or market value, so no information in those fields results from this analysis. The reason for this is the previously mentioned lack of a definition of IoT in healthcare, resulting in conflicting figures when analyzing the total market and competitors. Because of this, in the resulting analysis a number of established manufacturers are located in the same category as newly developed startups as long as they were available in Europe and counted with either an FDA Approval or a CE mark. The source of this analysis and resulting categorization are market reports from Reports And Data[38], The Business Research company[39] and Fortune Business Insights[40]. The resulting companies and categories are shown in Figure 9.

The first category covers brands that offer a wide offering of devices and measurement possibilities. Some of the brands in this category, like Philips, also manufacture medical devices for general hospital use and have turned this expertise to a consumer-oriented market with a whole ecosystem dedicated to it. Other brands, like Withings, are completely IoT focused. By offering multiple devices, these brands have created closed ecosystems in which their products take part and do not have a high incentive to be open to data sharing with other platforms. Notably missing in this list are big healthcare companies like GE Healthcare and Medtronic, as even when they have a few products that would fit the definition of the analysis, it is not their main focus and they are not part of a fully capable ecosystem.

The second category are brands that are focused on a very specific medical necessity. Of the four researched examples, three of them have developed innovative devices to measure heart complications and can produce highly detailed ECGs (electrocardiogram), with another one focusing on reproductive health. While having a bigger incentive to share data with open systems or allow their users to have a wider range of decision, these companies tend to be smaller and therefore have a limited focus on development of integrations.

Wide offering	iHealth	Masimo	Philips	Withings
Specific medical use	CardioSecur (Heart)	Alivecor (Heart)	Praxasense (Heart)	Ava (Fertility)
Non-medical (lifestyle)	Apple	Samsung	Whoop	Calibrate

Figure 9. IoT device categories and main players in the European market, based on own analysis using information from Reports And Data[38], The Business Research company[39] and Fortune Business Insights[40].

The third category are brands that do not produce medical devices, but rather, wearables and services that are reaching the accuracy of medical devices. Two of these brands are Apple and Samsung with their flagship watches, both of which are FDA approved for heart measurements and are integrating new measuring capabilities with each generation. Despite being the devices made by the larger companies and belonging to the biggest ecosystems of the analysis, sharing of the data produced by these devices is the easiest of the three categories. The other two companies use wearables or 3rd party information to create health and fitness plans.

2.4.1 IoT medical devices as consultation helpers

Wearables and other devices capable of producing medical-accurate readings are becoming more common, and they pose an opportunity for the treatment and early detection of diseases. Special attention is given to heart conditions like atrial fibrillation, as watch-based wearables can now produce high-accuracy ECG recordings over a period of time that make the discovery of the condition four times more likely than a single reading with a specialized device[3]. This special focus on heart conditions can be seen also in the IoT medical devices that are being developed with only this use in mind.

Despite improving in measuring accuracy, doctors still have a hard time accepting the data from medical devices[39]. Two important reasons are behind this, the first one being that as it is a consumer-focused product, it seeks to give a medical diagnosis but often fails to do so accurately. A study from patients from the Mayo Clinic found that from 264 patients that received an alert of abnormal heart rhythm using an Apple Watch, only 30 (or 8.8%) ended up receiving a diagnosis of atrial fibrillation after their visit. This amount of false positives causes anxiety in patients and may take doctor and patient time unnecessarily[40], leading to healthcare overutilization. The Apple Heart Study found equally trending results[39], with 2,161 participants of the study receiving an alert and following up with a visit to the specialist, but only 34% of them receiving an atrial fibrillation diagnosis. The second

Figure 10. The Apple Heart study ran from November of 2017 to August 2018 with over 419,000 participants which shared recordings of their heart rhythms with Apple to search for signs of atrial fibrillation, receiving an alert on their watch if such signs were found.

"The promise of technology in medicine is to provide composite, panoramic views of individuals' medical data; to improve decision making; to avoid errors such as misdiagnosis and unnecessary procedures; to help in the ordering and interpretation of appropriate tests; and to recommend treatment."
Eric Topol, MD[14]

reason is that, as the quality of the data is still questionable, doctors are adamant to include it in official medical records as they might have a limited clinical applicability[41]. Another concern specific to this applicability, is if despite not knowing how to interpret the data but by having access to it, they would become liable if an adverse event happens to their patients[41].

The previously mentioned reasons often combine to create a situation in which doctors will not trust devices at this current moment, and because of this, they will fail to keep themselves updated as devices grow in accuracy. The result of this snowball effect is that, despite the devices gaining approval of health regulators around the world, they will still not be used as sources of medical information.

Participant	Age	Duration of interview	GP experience
P1	21	18 min.	In-person
P2	25	15 min.	In-person
P3	25	13 min.	In-person
P4	24	12 min.	In-person
P5	30	28 min.	In-person
P6	24	18 min.	In-person
P7	26	17 min.	In-person
P8	27	15 min.	Online
P9	26	14 min.	Online

Table 1. List of participants of the user journey interviews.

2.5 Exploring the journey of patients in GP services

In order to understand the application of e-health in the context of the COVID-19 pandemic, nine short open interviews were done between April and May of 2020. The objective of the interviews was to identify the journey of real patients, with a special interest in touchpoints and emotional experiences, from the moment of decision to the end of the GP service. The combination of experiences was delivered as a journey map.

This journey map exercise aimed to:

1. Identify the important elements of the GP service
2. Understand the links between touchpoints over time
3. Identify problem areas
4. Create empathy towards users of the system

Sampling for the participants was determined to be criterion sampling, finding online for people that had attended an appointment with a GP in the last year. This criterion was established as the effect of the pandemic was a point of interest. A proposed criterion was that participants had done this appointment remotely, but not enough participants covered it so it was integrated as a point of interest in the study but not a as a scoping criterion in the sampling. A possible reason for this that emerged later in the interviews was that some

patients preferred to delay the visit to a GP until in-person consults were possible.

Participants were asked to recount a single event in which they needed to consult a GP. The interview was open but asked participants to recount the experience in four different parts:

1. The decision moment of making an appointment.
2. The moment leading to the appointment.
3. The appointment.
4. Post-appointment.

Interviews were recorded with a phone application and later transcribed with the help of online tool Otter. The results of the interviews were later analyzed as post-it notes quotes and grouped.

Purpose of visit

Most interviewees, five, reported that they decided to consult a GP due to a sudden physical ailment that did not constitute an emergency, followed by treatment from a chronic ailment in three cases and a final interviewee did so because of an accident that did not constitute an emergency. The relevance of pain was mentioned through the interviews, as pain was the main cause of seeking medical attention. Pain was also understood to be a critical factor in deciding if the issue was an emergency.

"I was unsure if my case was an emergency, I was hurting but I was more worried of being told it was nothing than of it being something serious." -P2

Physical ailments were the cause of visit for all interviewees. In the cases in which a non-physical ailment was mentioned, it was connected to the former and did not constitute the main reason for the visit.

"I know I can discuss any topic with the GP, but I felt rushed and was told that I had to make an appointment per issue." -P7

Searching for information

All of the interviewees that had a non-emergency ailment that was the cause for the visit mentioned asking for an opinion to people close to them. Some of them considered not going to the GP but finally decided to, mentioning as well some other situations in which they also believed they needed to go but did not.

"I asked my roommate to take a look at the burn, it was red and I was in pain, but what finally got me to make the appointment was that the skin started to peel off. It scared me and him a lot." -P3

Those with less clear symptoms often looked for them online, with a simple google search of all the symptoms being the preferred option. This led to a lot of disinformation and an added feeling of worry towards their ailment.

"I know it's a joke that it will just say you have cancer, but it really did! More than scared I was just worried that I was not finding anything useful to help me diagnose what I had or what to take to reduce my discomfort." -P4

Getting in touch

Most of the interviewees did their interview on the telephone, with a total of six doing this. Three others did so using the e-health system of their GP, in all cases this was the MijnGezondheid platform. Five interviewees were given appointments the next working day, and four of them were given appointments the same day.

"I had to push a bit for the appointment, I do not think they considered what I had a pressing matter but I finally got something almost at the end of the day. I also had to wait a while in the waiting room but it was ok." -P4

The effect of the pandemic was very notorious during this stage of the appointments, as some interviewees mentioned that they delayed treatment due to the insecurity of the status of their GP consultations. Upon calling, however, in most cases they discovered that services were, mostly, as usual.

"I had a nasty onset of allergies just before the summer, but I preferred to ride it out instead of going to the doctor for a new prescription then. It just did not seem safe. I thought about doing the same with this but my mom told me I should had it checked out." -P8

GP consultation

Some interviewees had already looked for symptoms online and were curious to see if the GP agreed with their own diagnosis. In some cases, it was, but the general response of this diagnosis by GPs was not welcomed in all cases, as they believed that the symptoms, they were interested were those being exhibited by the patient and not those they believed fit their "internet-found" diagnosis.

"I mentioned my doctor that I searched for my symptoms online and she laughed." -P5

The accuracy in symptoms was also an issue during the consultation, as it is not easy to pinpoint certain things like location of pain or strength. Remembering was also an issue, as some pain, for example, was only present during certain moments of the day or activities but during the excitement and rush of the appointment it was fuzzy when exactly they happened. Some interviewees also mentioned their lack of rapport with their GP as a reason to mask pain as lower than it was or certain habits.

"I had smoked a bunch during the exam week, and of course my asthma got ramped up. When the doctor was hearing my lungs, I assume he heard something strange because he asked me, but I did not told him, I did not want him to write it on the record." -P1

Taking metrics

According to Atul Gawande in his book "Complications"13, medical convention dictates that the four vital signs critical to assess the physical state of a patient are temperature, blood pressure, pulse and respiratory rate. Additional measurements like weight and height help to establish baselines to be used in treatment and to evaluate changes over time. Not all measurements were reported to be done by all interviewees. A possible cause for this is that as some interviews were done on consultations that happened in the past, the specific fact of taking this measurement is not remembered. Another possibility is that the specific measurement was not relevant to the consultation or the data from a past measurement was still considered valid.

"When she placed my arm in the band, I got nervous, well, I do it all the time. I try to control my heart rate or breathe slower but I do not know if it messes up the measurement. She told me what it was some number, but I do not understand that, I just asked if it was good or bad." P5

Specialized measurements like glucose levels for diabetics are also important in general practice, but as they are meant to be taken over periods of time, they need context to be correctly understood. A similar situation happens with blood oxygenation, a measurement that took special importance during the COVID-19 pandemic due to the increased risk of hypoxemia 44, as multiple measurements over time are necessary to establish a pattern and its use as a single measurement is limited.

"I asked him about the blood oxygenation thing that they mentioned with COVID-19, but he told me I was fine and did not need that test." P2

Receiving a diagnosis

When the doctor communicated his findings, some interviewees failed to follow the rationale of the diagnosis and understanding the next steps. Most consultations ended with an agreement to return if their situation worsened or for a checkup after a few weeks. The most common scenario was two weeks. In two cases they were recommended not to return unless a new development happened, likely due to a rise in restricting measurements during the period in which this appointment was done.

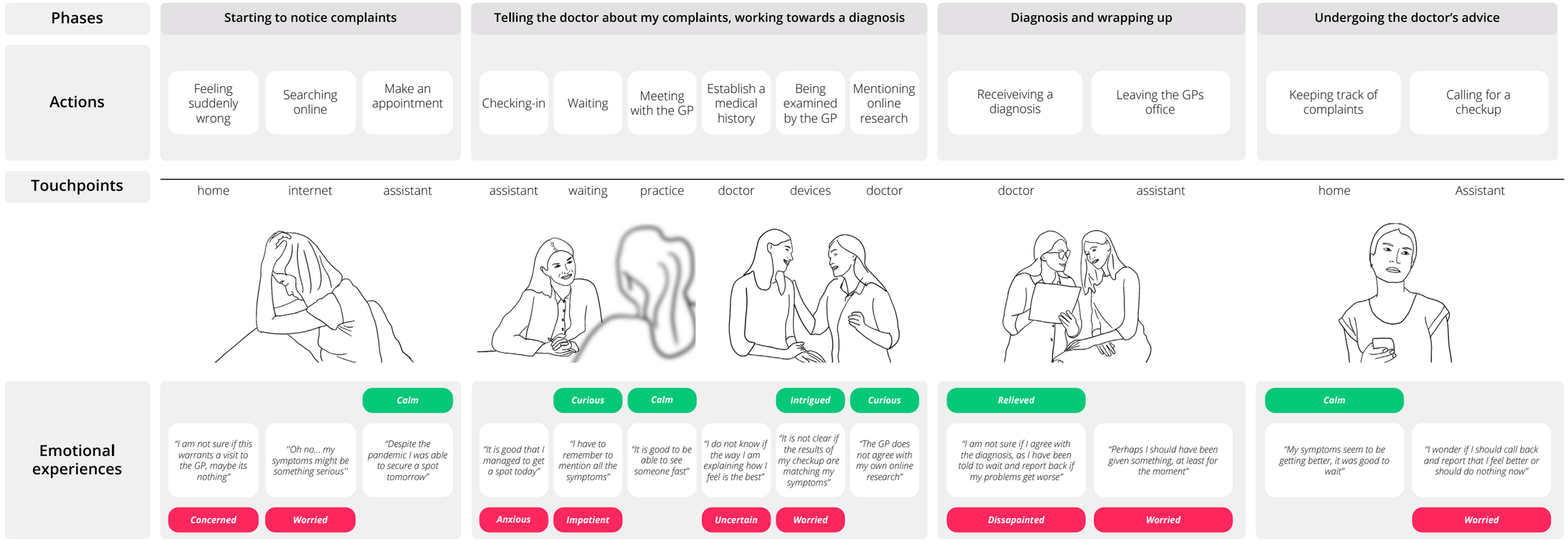


Figure 11. Resulting journey map from the exercise.

"Nothing happened during the consultation, he just told me to get back if it got worse, I did not get back because it got better, but still." -P6

A cultural difference that was very clear in this stage was the expectation of medication by some patients, this lack of a medication led to some patients not believing that they were taken seriously or having the feeling that their ailment was not going to heal and the overall feeling was that of lack of closure.

"I was waiting for a prescription or something for the pain, but the prescription was the same as what you can get at Jumbo." -P6

After the consultation

A similar point of concern for interviewees in which this was their first GP experience was if it was covered by their insurance and if medications were as well. Some anxiety was also reported by the patients that mentioned the lack of closure. However, in most cases a sense of calm as reported as their ailment had been heard, independent of the diagnosis itself.

"The doctor was very into to what I was telling, and he asked a lot of questions, in the end it turned out to be nothing but I felt like he did care about what I was talking about." -P1

“The main reason [for the box] is that healthcare professionals have more and more pressure on their shoulders, they are really busy and they wanted to see how to remove a bit of work for them.”
– LUMC Design researcher

2.6 Connecting IoT devices into a service: LUMC The Box

There were very few instances during the interviews in which devices were measured, as the consultations mostly revolved around a conversation and physical analysis. When compared with the two online appointments, it was clear that the lack of physical access meant that diagnosis was somehow impeded and instead relied on further questions to achieve the same level of accuracy.

In order to understand how IoT medical devices can be connected and used as a helper for remote consultations, the case of The Box by the Leiden University Medical Center was analyzed. This project aims to deliver a box containing a number of medical devices that are used as follow up for certain patients, like those that have suffered a myocardial infarction. The devices connect to an application that sends the information directly to their physician in LUMC for analysis. The box started with a focus on heart ailments, but as a modular kit, it can be modified to accommodate the required devices to follow on others. Currently, different versions of the box exist, such as those aimed at following a pregnancy and during the pandemic, a box was developed to give a follow-up to patients that had contracted COVID-19. The Box in its myocardial infarction version includes a pedometer, a blood-pressure monitor and a heart-rate monitor. Other versions include other devices like a scale, thermometer and oximeter.

An interview with a design researcher embedded in The box was done to further understand the implications of the project. The interview was guided along the line of the integration of medical devices and the effect his has on people, the use of data and the future of the project.

The case is relevant because the LUMC managed to cross the important barrier of connecting devices of different manufacturers to an integrating application that reports directly to the EHR of the hospital. This is necessary as a single manufacturer does not offer all the measurements that are needed for the patients. Currently, most of the devices are manufactured by Withings, that allows for a data export to the application of LUMC. Over the course of the development of the box, several devices have been changed and the procedure of sending measurements to the hospital has been improved. Despite this, patients still need to use at least two different apps in their phone to take the necessary measurements and send them to their doctor, this is confusing for some patient and leads to some of them discontinuing the use of one or more devices. Another reason for abandoning a device or the box as a whole is that as patients improve, they feel like they do not need to keep making measurements.

The box allows doctors to focus on patients by relieving them of manual work. The information that is gathered is used to analyze the improvement of the ailment and a team of data researchers in LUMC is also working on ways to use it to predict future events.

Figure 12. The physical box that patients receive and some of the devices of the program. Visible here are the MightySat Rx oximeter of Masimo, the Thermo thermometer, and BPM Connect blood pressure band, both from Whitings.

“I think why it’s so successful is that it’s really gained from them [LUMC] internally. It’s really aligned to how they work and how they want to receive data.” – LUMC Design researcher

2.7 Trend analysis

Starting from the relevant topics found on the contextual research, a process was followed to find relevant trends for the future. The trend analysis was done using the Trend Patterns technique of the Design Roadmapping process. The first step for this was to review the contextual research for the basis of immersion and identify those subjects that required more information. After this, patterns were created by joining the information together. In total, four trends were identified.

2.7.1 From wearables to passive sensing

Medically-accurate wearables are becoming more and more common. An example of this is that in 2021, the ECG capabilities of both the Apple Watch and the Galaxy Watch received FDA authorization[45]. This is a trend that will continue as more capabilities are integrated into them. Researchers around the world are working on imaging sensors that can detect blood pressure and temperature without needing to physically touch a person[46], and are likely to be integrated into wearables or other devices in the coming years.

Parallel to the development of wearables and their integrated suite of sensors, are technologies that can be described as passive sensing. These non-contact sensors do not require touching, or in some cases even be near, the person they are measuring. Examples of these technologies exist both in hardware and software form. In hardware, they exist as sensors like doppler radar and cameras that can see an array of different wavelengths[47]. In software, they are the machine learning algorithms that allow the data from sensors and cameras to be translated into comparable measurements.

Just as wearables are becoming as accurate as medical devices, passive sensing is expected to become as accurate in the future[48]. Most of the increase in these systems relies on analyzing new datasets in order to account for user characteristics that in the existing systems require to set a baseline with a dedicated medical device. Systems that use these technologies are already successfully used in medical studies, like the observational study by Thakur et al. that presented a model for predicting clinical event during dialysis

	Device category		
Characteristics	Dedicated devices	Wearables	Passive sensing
Vital signs that can be taken with current technology:	All four: Temperature, blood pressure, pulse and respiratory rate.	Three: Temperature, pulse and respiratory rate. Blood pressure in advanced stages.	Two: Temperature, and respiratory rate. Other two in advanced stages.
Other measurements:	The standard.	ECG, blood oxygenation, sweat chemistry.	Glucose levels
Accuracy:	Highly accurate.	Highly accurate.	Some measurements need a strong baseline on the user, needing a calibration with another device.
Type of sensing:	Per event or continuous.	Continuous sensing and some characteristics per event.	Continuous sensing.
Interaction:	Contact.	Contact.	Non-contact.
Measurement technique	Pressure, surfaces, light reflection.	Pressure, surfaces, light reflection.	Surfaces, camera, radar.

Table 2. Categorization of medical devices with key indicators. Sources in text.

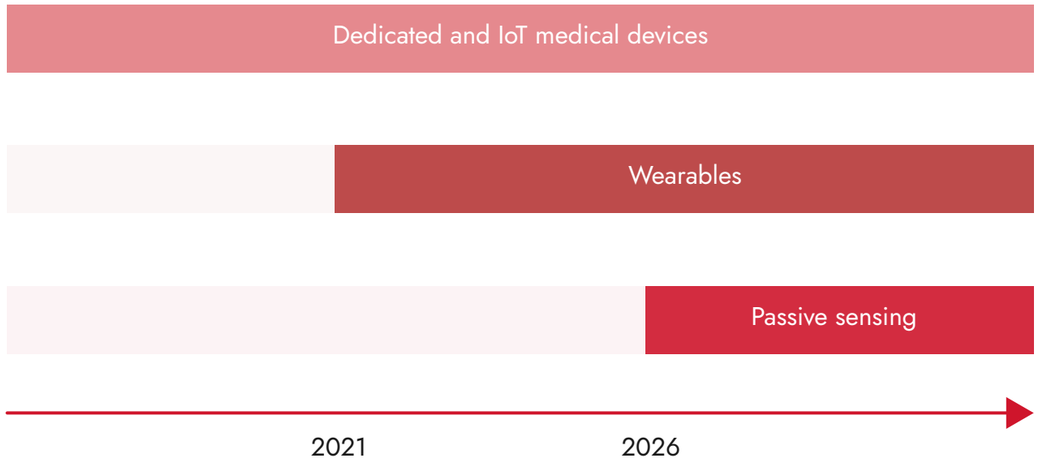


Figure 13. Expectation of the ecosystem of medical and medically capable devices, with passive sensing becoming a source of medical information in the near future. Result of own analysis, sources in text.

using non-contact sensors[48]. Despite its growing capabilities, most passive sensing examples today (with the exception of temperature with IR cameras) are academic. Even with this prediction, passive sensing is more likely to add capabilities to the medical device ecosystem as wearables are doing instead of outright replacing one of those categories. The result is that manufacturers in the future will have a wider range of options to gather information about the habits of people with both contact and non-contact sensors.

Expectation of the ecosystem of medical and medically capable devices, with passive sensing becoming a source of medical information in the near future.

2.7.2 Smart tracking of food habits

The rise of the smart home has also expanded to the things we eat, with a number of appliance systems already working on tracking food with different purposes. One of them, and the most prevalent, follows the value of food safety, integrating technologies like blockchain to track food recalls and avoid the consumption of unsafe food. Other systems aim to connect users with recipes for the food they already have and help with the preparation of recipes, integrating technologies like cameras and barcode scanners. Not present in appliances but prevalent in applications is food tracking, from solutions that use machine learning to identify food on photos to connection with a smart mug that can identify what kind of drink is present and the calories that it contains.

2.7.3 Chronic diseases and food

The rise of industrialization and urbanization of the world was both a cause and an effect for the rise in the consumption of heavily refined foods. While these foods have a myriad of benefits, like a long shelf-life that reduces the stress on distribution networks, they also present important negative health effects if consumed regularly. These effects represent an elevated risk of developing into chronic diseases like hypertension, diabetes and Alzheimer.

Chronic diseases are the leading causes of death worldwide, and is expected to contribute in 2020 to 73% of all deaths and 60% of all the burden of disease . The four most prevalent chronic diseases are cardiovascular diseases (CVD), cancer, chronic obstructive pulmonary disease and type 2 diabetes[49]. Among the risks factors for these diseases are behavioral risk factors like an unhealthy diet and physical inactivity.

The rise of urbanization is also a cause for a sedentary lifestyle that increases the risk of obesity and diabetes, this is especially true in emerging markets that are shifting from a rural context[50]. This increase in sedentarism is also related to the ingest, or lack of, of certain foods that were found to have relevant links to mortality. The most important of these food factors was excess sodium in food, followed by not eating enough nuts and seeds[51]. Food habits have a clear effect on the onset of diseases and our perception of wellbeing.

With most of the expenses in medical treatments around the world already devoted to chronic diseases, important strides are being made in the field of preventable medicine. Medicine as a field is shifting from only focusing on the diagnosis of disease, to a holistic approach that starts well before an ailment is detected and does not end when it is considered cured.

2.7.4 Nutrigenomics

Nutrigenomics is a field that aims to explain the effects of food in your body by tying it to genetics[52]. As a field, it is relatively new and depends on advances that allow us to map the genome of individuals at a rate high enough to have enough data to support predictions. The basis behind it, however, have been around for centuries, with nutrigenomics offering now a scientific explanation to the reason why food on a particular person has a different effect than on another one.

Chapter 3:

Arçelik and healthcare

3 Arçelik and healthcare

Following the research into e-health and its expansion by the COVID-19 epidemic, it became necessary to limit the scope of the project to a specific opportunity. For this, a focused look was taken at the activities that Arçelik already does in the healthcare domain and the alternatives that exist for a wider integration of e-health capabilities in their current products.

3.1 Current presence of Arçelik in the medical device market

Arçelik does not currently have a direct and continuous presence in the medical device market. It does, however, have three single products that are offered at such market and offer medical capabilities. These products are not part of a general push towards healthcare and the medical device market and instead are seen as innovation demonstrators of different business units. The products, like those of competitors, are also not integrated into a single platform nor are meant to work with one another.

3.1.1 Corensis medical kiosk

Corensis is an AI-powered measurement terminal that offers automation of measurements with high precision medical sensors and a platform outfitted with advanced diagnostic algorithms. The kiosk aims to accelerate the registration step of the patient, with an AI-driven assistant asking follow up questions regarding the patient's medical history and symptoms. A final report is created by the kiosk and sent to the doctor or nurse.

Figure 14. Corensis medical kiosk. Photo credit: Arçelik.

Corensis is a Class II-B medical measurement device and has a CE mark. Corensis was developed by the Arçelik innovation team and Omuus Design Agency.

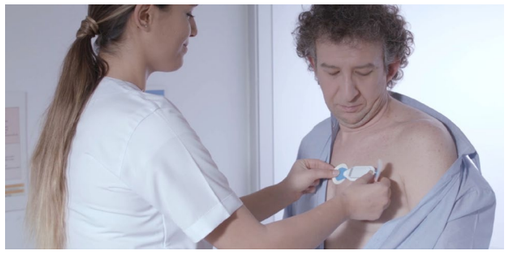


Figure 15. BeyondCare ECG monitor. Photo credit: Arçelik.

3.1.2 BeyondCare ECG monitor (Holter monitor)

BeyondCare is a wearable ECG monitoring system that allows remote monitoring of vital data such as cardiac rhythm, respiration, activity and body temperature. The product is an innovation of a typical Holter monitor, which purpose is to record the electrical activity of the heart over long periods of time.

	Corensis	BeyondCare	Biyovent
Category	Medical kiosk	Holter monitor	Mechanical ventilator
Status	Not yet commercialized	Commercialized product	Commercialized product
Main customer	Hospitals	Hospitals	Hospitals
User authentication	ID number, facial recognition	No	No
Main measurements taken	Body temperature, oxygen saturation, ECG, blood pressure, body mass index	ECG, activity	Over 30 ventilation monitoring parameters
AI processing capabilities	Yes, cloud-based processing is done to obtain an enriched single page report	Yes, cloud-based processing is done to obtain analysis of heart health, physical condition and sleep patterns	No, smart ventilation monitoring is advertised
IoT capabilities	Yes, Wi-Fi and access with proprietary platform	Yes, Wi-Fi and access with proprietary app	No
Class and approval	Class II-B medical measurement device, CE mark	Class II-A medical measurement device, CE mark, FDA Clearance	Class II-B medical measurement device, CE mark

Table 3. Overview of the medical products of Arçelik and their main characteristics.

Clinical studies for BeyondCare were carried out at Koç University Hospital, has a CE mark and FDA clearance[53]. BeyondCare was developed by Rooti Labs.

3.1.3 Biyovent mechanical ventilator

Led by the Turkish Ministry of Industry and Commerce and the Ministry of Health, Arçelik joined Turkish defense companies Baykar and Aselsan in a team effort to develop a mass-produced version of the Biyovent mechanical ventilator designed by startup BIOSYS. By June 2020, 5,000 devices had been produced at Arçelik's Electronics Plant in Çerkezköy [54], with more than half being donated to 14 countries and the rest being used to cover the expected local shortage.

Figure 16. Biyovent mechanical ventilator. Photo credit: Arçelik.

Biyovent is a Class II-B medical measurement device and has a CE mark.

3.2 Barriers of entry of the medical device market for Arçelik

A mentioned earlier, Arçelik is not successfully positioned in the medical device market. This market is distinctively different to the appliance market that Arçelik already operates in, and in order to become a competitor, three main barriers of entry were identified:

3.2.1 Heavily regulated industry

The healthcare market, and specifically the medical device market, is heavily regulated by organizations like the FDA in the United

States, the Medicines and Healthcare products Regulatory Agency (MHRA) in the United Kingdom and the MDD in the European Union. These regulations are meant to control the risks to human life, but they provide a significant limitation to innovation. In a general sense, the role of these organizations is to ensure the safety and effectiveness of high-risk medical devices. However, they heavily rely on manufacturers to identify and correct problems[55]. This reliance on self-regulation creates an additional advantage for established companies that already count with significant assets on health research and the capacity to use predicates to speed up the approval process. Of the three medical devices Arçelik has developed, all of them have a CE mark and only one of them has FDA clearance.

A way in which new manufacturers have been entering the medical device market without needing to follow the regulation process is by offering their products as of informative nature instead of medical. The FDA provides this workaround if the product is intended as informative or general wellness, and as long as it does not claim to diagnose or treat any medical conditions. This process is helpful to manufacturers as a way to perfect their product before applying for the compliance process and has been done by Apple with different characteristics of the Apple Watch. The application of this by Apple is also innovative in the way that, a feature like the EKG monitor on the Apple Watch 6 is FDA cleared for diagnosing atrial fibrillation, but the blood oxygen monitor on the same watch is not FDA cleared and is labelled instead as of informative nature only[45].

3.2.2 Established competitors

When talking about medical devices and not only IoT medical devices, the clear definition of the regulating authorities provides a clear scoping of the market. This market is estimated to be worth USD 423 billion in 2020[40] and is composed by at least 50 relevant competitors[39], five of which controlled 25% of the market between them in 2017[56].

Of these five companies, the top three are based in the United States, with the remaining two based in Europe. Overall, the market is considered as heavily consolidated. It is also important to note that, with the exception of Medtronic, all of the companies in the top five and most of the top fifteen of market share are part of industrial conglomerates have developed medical technologies since at least the beginning of the 20th century.

The size of the competitors is also reflected in their R&D investments. The top five companies lead the way in forecasted investment in 2024, with an average of 7.3% of sales being spent on R&D, compared with an average of 7.1% of the rest of the market. Within the top five, the biggest forecasted spender for 2024 is Philips with 11.8% of sales that translates to USD 2.2 billion.

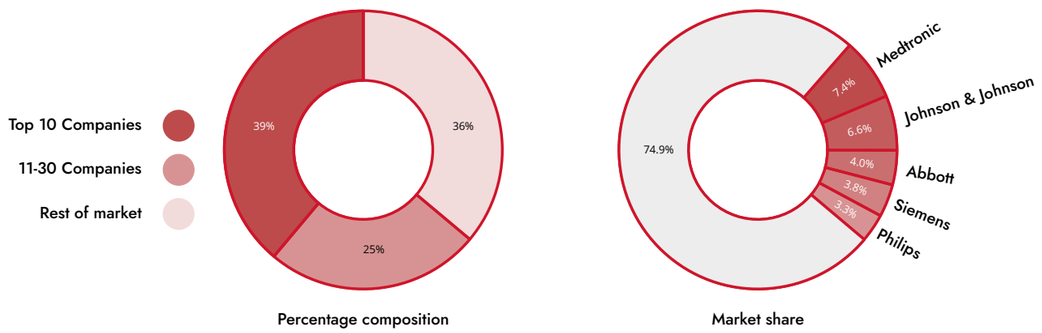


Figure 17. Overview of the medical device market, adapted from EvaluateMedTech[56].

3.2.3 Mature segments

Most of the previously mentioned companies have a very specific focus within the healthcare domain, with very few of them competing in a wide array of segments. All of the top five competitors of market share dominate a category, or are a close second or third in two categories. The FDA panels list serves as a guideline for locating these companies in their respective fields, and five different categories will be used to explain the specialized focus of companies in the medical device market:

- I**n Vitro diagnostics:** These products perform the testing of samples that have been taken from the human body, typically blood or tissue. In this category, Roche is the market leader with 19.5%, followed closely by Abbott with 10.7% and Siemens with 8.9%.

- **Cardiology:** In this category medical devices like pacemakers and implantable defibrillators are found. Medtronics is the market leader in this category with a 24.2% market share, followed by Abbott with 17%.

- **Diagnostic imaging:** Products like Magnetic resonance imaging (MRI), ultrasound and fluoroscopy are found. The market leader in this category is Siemens with 23.2%, followed closely by General Electric with 22.2% and Philips with 19.7%. Of all the categories of medical devices, this is the second most consolidated, with the top three companies controlling a 65.1% stake and the top ten controlling 91.5% of the market.

- **Orthopedics:** This category is mostly composed of prosthetics, with most of the newest developed products being hip and knee replacements. Johnson & Johnson is the market leader in this category, with 24.2% of the market.

- **Ophthalmics:** This category encompasses a wide array of ophthalmic devices, from contact lenses to laser surgery equipment. The market leader in this category is Essilor with 26.5%, followed by Novartis with 21.7% and Johnson and Johnson with 14.7%. This is the most consolidated category of medical devices, with the top 10 of companies controlling a 97.9% stake of the market.

3.3 The medical device market is changing

With the introduction of novel technologies like AI and machine learning, many competitors have started to build medical devices with the hopes that such technologies will help them get an edge over traditional means. Since 2010, 64 AI/ML-based medical devices or algorithms have been approved by the FDA[57]. On some applications this is already true, and products already exist in which AI-powered data analytics overperform human operators, especially in the fields of radiology and cardiology. However, and for the majority of medical applications, these technologies have seen significant obstacles for its implementation.

Another important change is how technology companies view the interposition of these technologies in the health domain together with their current products. Apple and Google have both tried to integrate their healthcare products into platforms. The Google Health platform aimed at becoming the center of the personal health record of patients, but instead was met with poor user adoption and was shut down in 2011[58]. A similar service was added by Apple in 2018 to their Health application and has met a more successful path, having been continuously expanded through the years.

3.4 Wellness as the opportunity for Arçelik

It is necessary then to reevaluate the opportunities for Arçelik in the medical device market and in the wider healthcare domain. A first step towards this is to understand what health means and how it can be addressed from the point of view of Arçelik.

Health has many definitions, but one of the most widely recognized was coined in the 1940s by the WHO and it refers to it as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.[59]" This iteration became very important because it broadens the medical definition of health beyond the absence of disease. It is also very general, and invites you to use it as a vision of what health should be. According to the WHO, the primary determinants of health include the social, economic, and physical environments,

Figure 14. The six dimensions of wellness. Adapted from the National Wellness Institute[60].

and the person's individual characteristics and behaviors. The maintenance and improvement of health, accordingly, depends not only on external or environmental factors, but also on the efforts and intelligent lifestyle choices of the person. By this definition, it can also be concluded that the improvement of health depends and is augmented by wellness[4].

An important companion term to health is wellness, and in fact they are often interchanged. The definition of wellness is often dependent on context, and according to the National Wellness Institute[60], wellness is considered, "an active process through which people become aware of, and make choices toward, a more successful existence". In this characteristic, three core characteristics can be identified[4]:

1. Wellness is considered a conscious, self-directed and evolving process of achieving full potential

2. Wellness is multidimensional and holistic, encompassing lifestyle, mental and spiritual well-being, and the environment

3. Wellness is positive and affirming

Using these definitions, the difference between health and wellness is then understood that while health is a state of being and a goal, wellness is the state of living a healthy lifestyle[4]. Health refers to physical, mental, and social well-being; wellness aims to enhance well-being.

3.5 Alternatives for entering the wellness market

As with previous examples of technology companies, there are important alternatives for entering the healthcare market or integrating health capabilities by becoming wellness-centric. Some of these alternatives are already integrated into different brands and products of Arçelik.

Figure 15. HygieneShield product line. Photo credit: Arçelik.

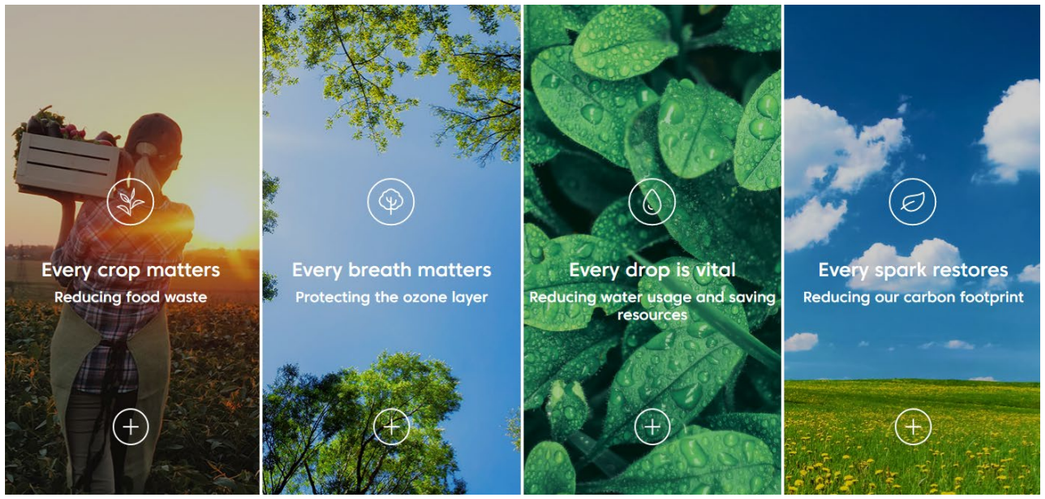


Figure 16. The main drivers of Beko's "Health at home" campaign. Photo credit: Beko.

Arçelik "Ultra hygiene series"

This technology is marketed as eliminating 99.9% of all virus and bacteria in certain appliances build by Arçelik, such as refrigerators and AC units.

Beko "Health at Home" Healthy Living is Only Possible on a Healthy Planet

This strategy joins personal and planetary health in a concept that champions healthy living and sustainability in its products. Examples of this are technologies and features to reduce the use of water and increase the life of fresh vegetables.

Grundig "Respect food"

Massimo Bottura joined Grundig with his non-profit Food for Soul to fight against food waste and inspire people to fight it from your kitchen. The capabilities of Grundig's devices offer new ways to prevent food from spoiling and to increase resource-efficiency.

As shown in these examples, the concept of health is used interchangeably with wellness as to define a holistic state and a healthy lifestyle. According to the previous definitions, it corresponds more appropriately with the one of wellness.

Figure 17. Grundig's "Respect food" strategy is aimed at lowering food waste. Photo credit: Grundig.

Chapter 4:

A future organizational vision

4 A future organizational vision

After the contextual research and the integration of Arçelik and healthcare, a value mapping session with representatives from the company was done in order to tie the findings to the values and operational interests of Arçelik and validate the scope of interest. The future vision that resulted was later turned into a strategy for the entry of Arçelik into a new market by integrating wellness capabilities across their devices.

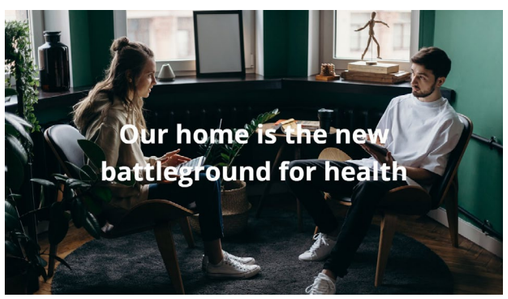
4.1 Preparation for value mapping session

The session was structured around the framework for a value mapping session described in the process of Design Roadmapping. The purpose of this session is to create a future vision that uses the results of previous steps[61]. The necessary adaptations were done to allow for its online application in a Miro environment. The session was structured around three sections and seven activities.

- The first section was an onboarding exercise in with the attendants introduced themselves and used some questions to both break the ice and practice using Miro.
- The second section gave a recap of the project and presented the conclusions from the research in the form of slides.
- The third section had four activities: The generation of values desires and wishes relevant for an e-health vision for Arçelik, the strategic value opportunities they contained, a description of the desirable future, and a final step meant to be critical with the created content and close in on a future vision.

4.2 Value mapping session

The value mapping session was attended by Arçelik personnel of diverse departments, with the titles of IOT & Business Development Manager, UX/UI Design Manager and Sr. Industrial Product Designer.



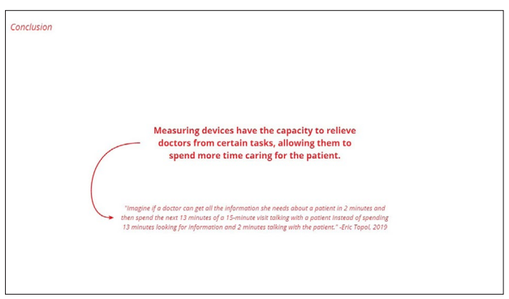


Figure 18. As the participants were not involved in the project so far, slides were used to get them up to speed and communicate the results of the research. Photo credit: Pexels.

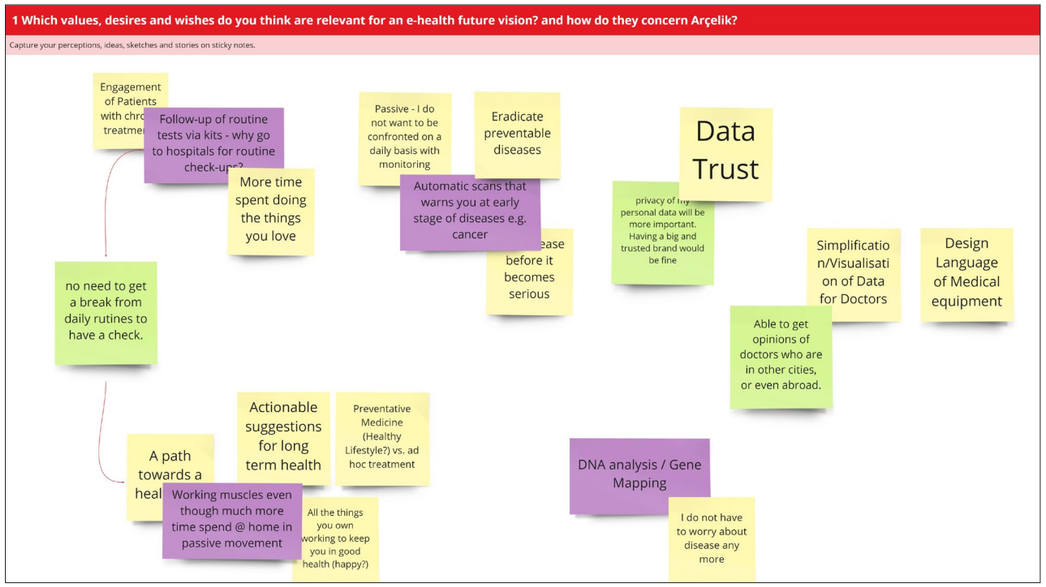


Figure 19. The first activity invited participants to identify the values, desires and wishes that were relevant to an e-health future vision for Arçelik.

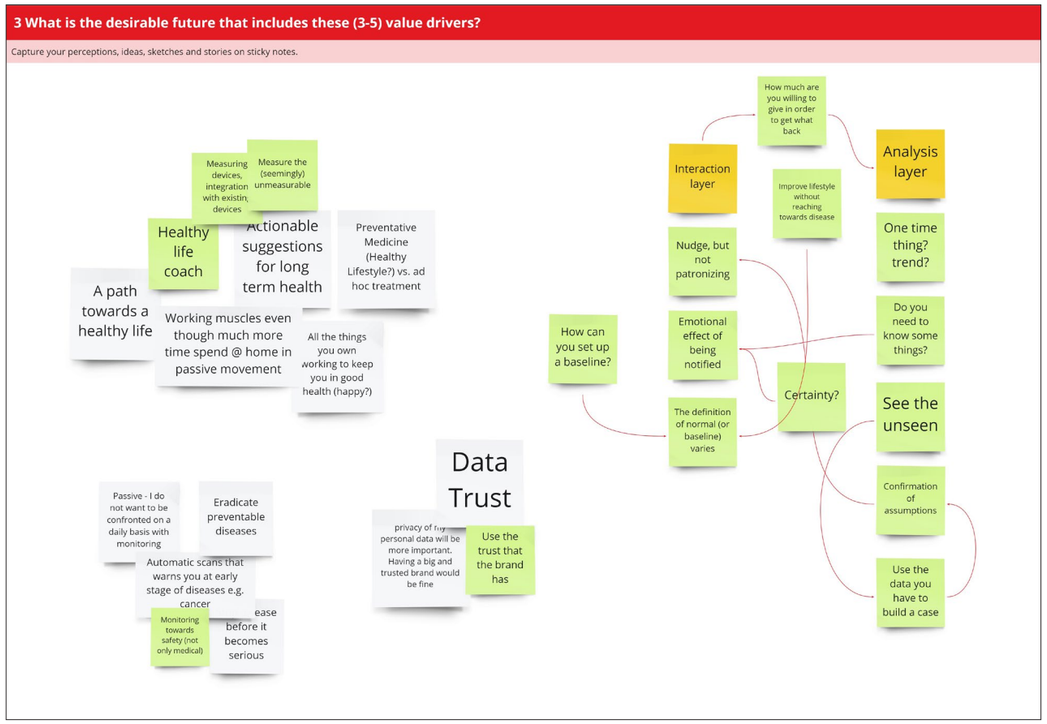


Figure 20. The first activity concluded by identifying the desirable future that included the value drivers identified during the exercise.

- In the first activity, four clear clusters of relevant topics for Arçelik were identified: Data trust, preventative medicine for a sedentary population, eradication of disease trough novel methods and the merging of at-home activities with the medical sector.

- On the next activity, value opportunities for Arçelik were attached to each of these topics. During the discussion in this stage, it was clear that some of the wishes would lay out of the scope of the project and gave us an interesting opportunity to scope down to what would be valued by both the current endeavors of the company and the customers. A key topic of the discussion on this activity was the trust that users already have on the brand, and how it can be used to reaffirm the safety of using a system that will deal with sensitive data. The focus of the company is also a relevant topic, as the chances of adoption grow if the focus of the system is kept general and not aimed at a narrow disease.

- The third activity converted these drivers into a desirable future, with the discussion leading to a multi-layered approach to data and analysis.

4.2.1 Future vision scenario

With the learnings from the session, a future vision in the form of a short story was formulated:

Ana wakes up in the morning and already some vital signs and measurements are updated in her profile. She stands in front of the mirror and a good day message is displayed, along with a connection to her schedule. When she goes to the kitchen, she is presented with a range of choices for breakfast that can be prepared with the ingredients she has with the benefits or tradeoffs based on her past history eating them.

As she is starting the day with a walk around her neighborhood, she takes a glass of soy milk (coffee first time in the morning doesn't work for her). She is also notified that her preferred after-walk breakfast is not ready to be prepared as she is missing some ingredients for her bowl of oats, and can then adapt her walk to pick them up at the grocery store.

Before going to work, she takes a bottle of Prosecco to the fridge and can see in the display the last bottles she drank. With this, she remembers that a bottle of white wine she opened last weekend was not very good and makes a note to not buy it again.

This future vision serves to showcase the vision of the strategic directions that Arçelik wants to take in the domain of health and wellness, and communicates the values and user interactions that will be key for the service concept resulting from this thesis work.

4.2.2 Organizational vision

The results of the workshop formed the basis of the organizational vision for e-health. This vision is composed of certain values and desires that are wished for in the final solution:

- The brand representation and trust are the main advantages of the company to execute this project. This is especially relevant to the markets in which Arçelik as present with that brand, and will need a further integration in markets in which other brands are used.

- Arçelik is not in a position, nor has the interest, to become an e-health provider or a producer of medical devices. Those devices that they have produced are technology demonstrators and are not currently being sold.

- Arçelik does, however, want to keep pursuing wellness in its products.

- There is a big opportunity of Integration with the current Arçelik ecosystem and HomeWhiz smart home app.

4.3 A strategy for wellness in Arçelik

Arçelik cannot and should not try to compete with medical device manufacturers, and instead should seize the opportunity to integrate smart wellness capabilities to their current products. Using that as a starting point, more capabilities can be added depending on the value they bring to consumers, and they introduce the possibility of creating new product definitions in the future that combine wellness and FDA cleared capabilities. This soft approach to medical devices, by labeling them as informative only, allows the company to grow their accuracy and the general proficiency of the company in that domain until it reaches a point in which compliance to regulations is possible.

Of the different appliance ecosystems in which Arçelik is present, the nutrition ecosystem presents the biggest opportunity per number of current appliances and of already deployed smart capabilities. Other ecosystems could be expanded or made from scratch.

Chapter 5:

Service design.

5 Service design

This chapter describes the process followed in the conceptualization of a service design solution. Starting with a scoping of problems to be taken into account that turned in a design goal. A later set of ideation sessions with stakeholders and users contextualized the problems into a real scenario, and culminated with the presentation of four concepts.

5.1 Problem definition

In the pursuit of wellness, there are many alternatives that help people track different aspects of their lives like what they eat and how they sleep. These systems, however, require a high degree of information input from the users and are, at best, only as accurate as the data that is logged in. This is further worsened by the little capacity that humans have at remembering specific aspects of our lives. Medical devices and wellness informational devices have the capacity to record this data more accurately, but most of them will only deliver a window into a specific point in time and have to be contextualized with their user story that is at times hard to recollect, as many of the points that interest health tracking are not things that people think about often.

Problems:

- Most medical devices focus their readings on a single point in time, and need to be contextualized in order to understand their implication. Example: Blood glucose levels are useful to determine the health of a user and to diagnose diabetes, but do not offer insight on the way the body process certain types of sugars or the time it takes to do it.
- Stories and habits are hard to recollect, leading to a chase of information. Added to this, some information might be purposefully hidden by the patients, hindering the process of establishing an accurate baseline. Example: A user might not know how often alcohol is consumed because alcohol units vary by type of drink, and if they do, they might hide it due to shame.

5.2 Design goal

Design a service for tracking life habits starting with the devices from the Arçelik ecosystem, with the purpose of helping users understand the effects of the things they do on a daily basis and with high accuracy.

This service is integrated in Arçelik appliances that allows users to lead a healthier life by working in three layers: Habits, effects and nudging. The first layer seeks to track what is being bought, eaten and thrown away. The second layer is meant to augment it by also understanding how food affects the person ingesting it, and is focused on effects on body and mind. A third and final layer combines both of the previous layers to maximize the positive effects by suggesting food, ways to prepare it and activities.

5.3 Ideation session

Parting from the design brief, a process was set up to develop the design concept. Starting with ideation sessions with stakeholders and users, a conceptualization stage to bring everything together and ending with a concept that could be evaluated. The ideation session was structured around six steps and was designed to last 1.5 hours.

- Warm-up and onboarding
- Presentation of research insights
- Activity 1: Describe a personal situation in a journey map
- Activity 2: Scan for opportunities in your journey
- Activity 3: Identify and separate opportunities
- Activity 4: Select and merge ideas into concepts
- Feedback on the activities

The first step of onboarding was designed to familiarize the users with the online tool Miro, quickly showing how to move around the board, how to edit elements and how to add new ones. After a quick introduction on these tools, they were tested by filling a table in which they answered several questions on themselves like “Tell us one thing about you” and “Tell us your opinion on pineapple on pizza”. These answers were later presented and were meant to kickstart the conversation and create rapport around the participants.

Once participants were familiarized with the tool, the next step was to present the project, objectives and results. This was done with two sets of slides in Miro, asking participants to stay engaged during the presentation by asking questions if they arose. This activity was finalized by presenting the problem definition and design objective, that would form the basis for the next activities in the session.

The first activity for participants was to describe a situation in which they needed to explain their symptoms or a medical history to someone in the search for a diagnosis. As the expectation at this moment was that the project would not incursion into strict medical devices, situations outside of the doctor’s office were encouraged. The format for this activity was designed as a journey map, as it allows for people to dissect their story in certain key parameters that could be used for later steps of the session. While it was not expected that all participants were familiar with the journey map method, its similarity with a mor common storyboard proved to be sufficient to do it without needing a lengthy introduction or special instructions. The journey map included the next parts:

1. Phase: Stage of the process
2. Actions: What you are doing
3. Touchpoints: Where is the interaction taking place
4. Emotional experiences: How are you feeling when you are doing it
5. Pain points: What is an obvious friction
6. Opportunities: How can this pain point lead to improvement (participants were asked to not fill this at the first activity)

Once the boards were complete with the first five points of the journey map, a quick round of presentations allowed everyone to get acquainted with the situations of their peers and ask questions about them. When everyone had presented, the next activity of finding opportunities y for the pain points was introduced and individual work began again. The instruction for the opportunities noted that not each pain point would have a clear opportunity, and they might be combined as well.

When the opportunities were filled, once again they were presented by the participants and at the same time were dragged into a new board to begin to identify and separate them into categories. The categories formed were mostly about similarities within the opportunities and solutions started to take

shape. Finally, these solutions and their relation to the pain points mentioned in the journey map were described.

A final question on feedback on the activity was asked to participants, in order to encourage any thought that might have arisen during the different parts of the session and to improve the outcome of later sessions to be done.

5.3.1 Results from ideation session with stakeholders

The value mapping session was executed remotely and attended by Arçelik personnel of diverse departments, with the titles of Senior Product Designer, CMF Designer, Sr. Industrial Product Designer.

The session was executed with three different participants that recounted four different stories:

1. A pounding headache that was followed up with a GP visit and later a neurologist appointment

2. A parent taking care of a child with a headache that slowly improved without going to the doctor

3. A headache that turned out to be a vision defect that was fixed with a spectacle's prescription

4. A very painful stomachache that was feared to be appendicitis but was luckily just gastritis

From these stories, five different clusters of opportunities were formed:

1. Access to information: Relating to the capacity to recall important information when necessary. Especially when involving serious cases, the capacity to recall information was greatly diminished and was a problem. Also, because these serious cases can happen at night or during non-working hours, obtaining a referral from another professional can be a hassle. From these issues the opportunities were formed in a system that allowed an easier access to both medical and non-medical behavior information to have at hand when it could be required.

2. Understanding symptoms: When feeling ill or otherwise not good, understanding what is happening can be difficult and it is also hard to explain to others. For this, ideas around categorization and identification systems were formed.

Figure 24. Participants in the remote ideation session were presented with a template of a journey map to fill with their own experience.

These systems would allow for a sequence of activities that can be followed in order to better understand how you are feeling.

3. Testing and devices: When needing more information about key metrics like vitals, a visit to the GP or laboratory is usually necessary. With the advent of new options to test at home, certain tests could be instead part of the daily routine of activities that we are used to now. Some of the tests would take the shape of the now very common COVID-19 self-test and others would require a device in the home

4. Validity of data and trust: In order for self-reported information to be as accurate as possible, an understanding of the dataflow needs to be clear to people and provide a certainty that it will not be used for the wrong purposes. This transparent dataflow can be designed into systems, with reporting on how the data is being handled and how it is used. Another important aspect of this is that data needs to be able to be controlled by the user at all times, introducing features like deleting certain metrics that will have an impact on the outcomes of the system.

5. Guidance to next steps: Even when the symptoms and the situation can be understood, it is sometimes not clear what follows next. Embedding certain key tasks on already used applications like calendar or notes can help to make life-changes stick.

5.3.2 Results from ideation session with users

The session followed the same steps as that with the stakeholders, but as it was executed in-person it allowed for a more personal follow-up on the situations. Three users aged 25 to 27 took part in this session.

The session was executed with three different participants that recounted three different stories:

1. A dizziness that appeared out of the blue and was taken care of after a call with a family member and off-the counter medication.

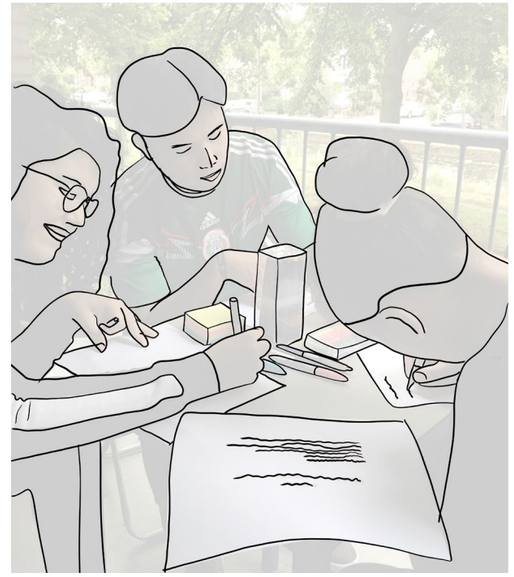


Figure 25. Photo of the participants of the in-person session filling their experience on blank paper.

2. A pain that did not subside and turned into fever, ending with a medical diagnosis after a GP consultation.

3. Feeling dizzy and with labored breathing after working in an elevated platform for almost a full day, ending with a consultation with a local paramedic and a prescription.

From these stories, four different clusters of opportunities were formed:

1. Accessibility of services: Medical services have a specific method, but medical needs sometimes take other shapes. Interim services between self-medication and a GP consultation should exist to facilitate the alleviation of disease.

2. Facilitate direct communication: Trying to explain symptoms or other historical medical information is difficult to do by memory, these opportunities related to logging mechanisms that would allow to share information as stories and part of a daily life.

3. Support networks: When feeling sick users usually turned to people close to

Figure 26. Photo of the participants of the in-person session clustering the opportunities they found on their journeys.

them for advice, these support networks represent an opportunity also in the category of preventative medicine as they can be used to create good habits.

4. Early signs of disease: It should be possible to stop disease before it begins, by identifying early signs of complications they could be avoided.

5.4 Conceptualization

After the sessions ended, a total of 33 different ideas were generated by the participants in different levels of fidelity and were analyzed for features and goals. This distinction allowed the information to be mixed and matched into different and new concepts. In total, the 33 ideas were assembled and augmented into four different concepts.

Concept 1: Food and activity tracker

- Key ideas: Track the effect of the food you eat at home to make better decisions.
- Strategic importance: Become the basis for vendor integrations.
- Integrations with current product ecosystem.
- Opportunity to create new products, especially in computer vision and passive sensing, ex, air purifiers and sensors, heat sensors and smart thermostats, scale mats, smart mirrors.
- Aiming at a healthier life by self-reporting.

Concept 2: An open healthcare platform

- Key ideas: Offer a platform that integrates health data from professionals, medical devices and wellness informational devices.
- Strategic importance: Become a main player in the healthcare market as a service integrator.

Concept 3: Medical devices for at-home measuring and testing

- Key ideas: Use state of the art technology to design accessible measuring and testing medical devices.
- Strategic importance: Allow access to incredibly detailed and accurate data, allowing the development of prediction algorithms.

Concept 4: A mirror into health

- Key ideas: provide a physical place to take care of your health at home and connect with medical practitioners.
- Strategic importance: Become the integrator of medical services.
- The mirror is a window that lets you connect with others.
- Passive sensing and a mat provide the measurements in a single place.
- Passive sensors do not need to be approved medical devices if used only for information purposes.

5.4.1 Evaluation and merging

In order to develop the ideas further, key aspects of them were sketched as quick stories. These stories allowed them to be discussed with stakeholders and point out possible areas of opportunity or issues.

Within the design process, some ideas relating to wellness invariably led to ideas relating to more strict healthcare. These ideas were analyzed for value opportunities and were integrated into a single proposal.

Figure 27. Quick sketches allowed the concepts to be illustrated and guided discussions with stakeholders. Some features, like the connection with a doctor in your bathroom, were discarded in these conversations.

Chapter 6:

Service concept.

6 Service concept

arhealth is a service proposition that aims to help people be aware of their habits and the effects they have on their wellbeing, by integrating information from existing and novel products of the Arçelik ecosystem. This chapter explains the concept in depth, starting with a service description and user stories to contextualize how it works. Later, a validation with users and stakeholders was followed, ending with a design roadmap.

6.1 Service description

The system integrates four different tracking modules: nutrition, vitals, activity and sleep. And gathers information from dedicated devices in each of these modules. Current Arçelik products in the nutrition module form the basis of the system, with new smart products being enhanced with capabilities in the future. For the other modules, a current scenario proposes API integrations with products that currently offer such capabilities, like smartphones and wearables, and can be augmented in the future by Arçelik-made dedicated devices.

The system gathers usage data from appliances, such as data con products that are commonly bought and consumed, and brings it together in a platform that enriches this information with self-reported data. This data brings an extra layer of complexity that is not common in similar efficiency-focused tools, and aims to help people understand the effect that food has on them.

With nutrition as a base, each of the other modules seek to complement this information. The sleep module brings insight on possible effects that food has on the quality of sleep. The activity module can join what you eat to the performance you have and make an assessment of its effect. The vitals module tracks key vital signs across time, helping to establish a baseline for analysis that can help to detect irregularities when they are still barely noticeable by traditional event tracking means.

6.2 User stories

In order to better explain every module of the system, user stories following a design persona were created.

6.2.1 Persona

A persona allows a system to become more understandable, as it helps to relate to specific situations instead of a general outlook. For this exercise, several key characteristics for this persona were chosen. The age of this persona was chosen to be 28 years, that of a young professional and probably a first-time buyer of appliances. The rest of the characteristics can be seen on Figure 28.

Sarah Accountant - 28 Years

Bio

Sarah just moved to a new flat after living in the city in which she studied, she works 4 days a week and enjoys dinners with her friends.

Activities

-Having time for herself

-Outdoor experiences

-Cooking

Wants & needs

- Make a home out of her new place
- Wants to live healthier

Frustrations

- The commute to her work
- Distractions that impede her to reach her goals

Figure 28. Persona created for the explanation of the user stories and the application of the concept.

6.2.2 Nutrition

Goal of arhealth in this story: helping Sarah to keep track of the food that she has tried and the effect it has on her, so she can make smarter choices and smooth her shopping process.

1. Sarah goes to the pantry and opens a carton of almond milk, when she puts it in the fridge it lets her know that this is the first time she has tried it.
2. A few days later, when the milk carton is half-empty, a new message is displayed asking her for a quick rating on the type of milk.
3. Later, when the milk carton is done, it displays a message to remind her that it seems you are liking almond milk more than your usual oat milk, and invites you to keep trying new things like soy milk.
4. The next day, another carton of milk, this time soy, is opened by Jane and put into the fridge.
5. This time, her stomach of the user does not completely agree with the milk, and she does not think she will buy it again.
6. The next day, a message is displayed asking for feedback, after a thumbs down a follow up question is made to give the chance to explain the issue.
7. Once the carton is done or is not being drunk anymore, it displays a message reminding you that it made you feel bad and you should probably not buy it anymore, and invites you to reorder your past almond milk or another new product.

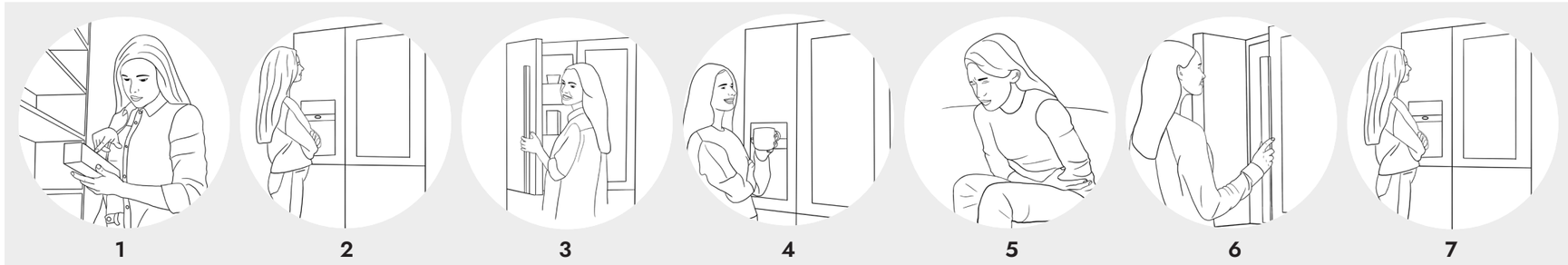


Figure 29: Nutrition user story.

The journey of this story follows a familiar procedure, trying something new only to be disappointed. The difference with this design concept is that by tracking things like rate of consumption and use, it can infer if a product is preferred over other. This assumption is either confirmed or denied using the self-reporting tool, and is an example of how the same action can lead to wildly different assumptions depending on how much information you have about them. This story also highlights a limitation of the system, as it can only track those things that you eat at home and in order to do this, it needs a way to understand who is eating what.

6.2.3 Sleep

Goal of arhealth in this story: help Sarah to track the effects of new habits on her life, and offer new alternatives to a healthier living

1. Sarah switched from coffee brands, she likes this coffee more than the previous one and sometimes she drinks two cups before leaving her house and has bought a new bag already.
2. When going to bed, however, she feels like she takes longer to fall asleep.
3. After a few days of gathering data, the system lets her know that her quality of sleep has decreased a bit and suggests to keep to decrease her coffee intake or try a soothing non-caffeinated beverage in the afternoon like chamomile.
4. With this actionable data, she goes on to try the chamomile tea.
5. After trying it for a few days, she sees that her quality of sleep has gone back to the previous levels, further suggestions like breathing exercises can also be followed.

This story follows a similar path than the previous one, with a user experiencing a change in the usage of products. The difference here is that, even when a product is not agreeing with us or is having a negative effect, we might want to consume it still. In this case, another characteristic of the system comes to light: that of learning from the behavior of users and using that information to supply alternatives. The system can mention these alternatives to people that are having a similar situation, and gauge the response. Another characteristic highlighted here is how both the nutrition and sleep modules are integrated, and enhance one another.

Figure 30: Sleep user story.

Figure 31: Vitals user story.

6.2.4 Vitals

Goal of arhealth in this story: help Sarah to keep track of her health measurements, and inform her when something she has done affected her baseline values and when this might need a second opinion.

1. Sarah wakes up and sees herself in the mirror in his bathroom, a message is displayed to let her know that readings will be taken with the passive sensors installed on it.
2. Meanwhile, the passive sensors and a weight sensor mat are taking measurements and updating her profile, analyzing this information against her baseline.
3. When the measurements are updated, quick results are shown showing baseline values and the values taken today.
4. This morning, his resting blood pressure is a bit higher than normal, and when compared with his weekly average, this week has been higher than normal
5. The system points that his consumption of highly salted food has increased by 20% this month, and suggests to Sarah to inquire about this.

While passive sensors offer a groundbreaking way of gathering information without the hassle of traditional means, they also mean that we could be under surveillance 24/7. It is then primordial to this system that the information follows a secure path, and that the user is aware of how this information is handled. Passive sensors that are being investigated today and can do the tasks shown in this story do so using cameras at different wavelengths, as the data to be analyzed is a video this brings the necessity to have a certain processing on the site of the device to make sure that this information is not transmitted somewhere else. Just as with the former example, the vitals module is deeply connected to the other three modules and while it has the capacity to act alone, the quality of the information that is gathered grows exponentially if it is part of an integrated system.

Figure 32: Activity user story.

6.2.5 Activity

Goal of arhealth in this story: help Sarah to improve her routine by trying new things and keeping track of their effect.

1. Sarah takes a cup of tea each morning after waking up and before going to her run.
2. This time, the system mentions that she could try to replace her cup of tea with a glass of water and take the tea after her run, as caffeine might have a negative effect during the run itself, and suggesting that she tries for a week.
3. After a week, the system shows the values of her run and asks if the change made her feel better.

This story highlights another possibility if all three systems are integrated: the quality of the assumptions grows, and therefore, also that of the recommendations. This example follows a general path of increasing hydration by cutting a known diuretic and replacing that with water. While the information on this suggestion is scientifically true, the effect it has on a user could be barely felt or it could make a difference. The importance of trying out new things then becomes that of finding out your own journey to wellness.

6.3 Data architecture

As shown in the user stories, certain characteristics require the concept to dwell deeper into the data flow. By exploring this, it is expected to bring a more realistic take on how the system could operate and the integrations that will be needed.

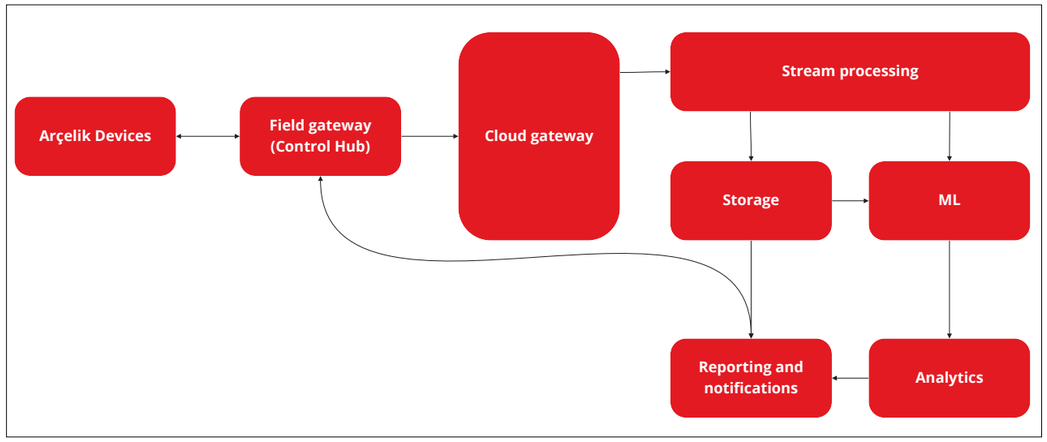


Figure 33. High-level data architecture.

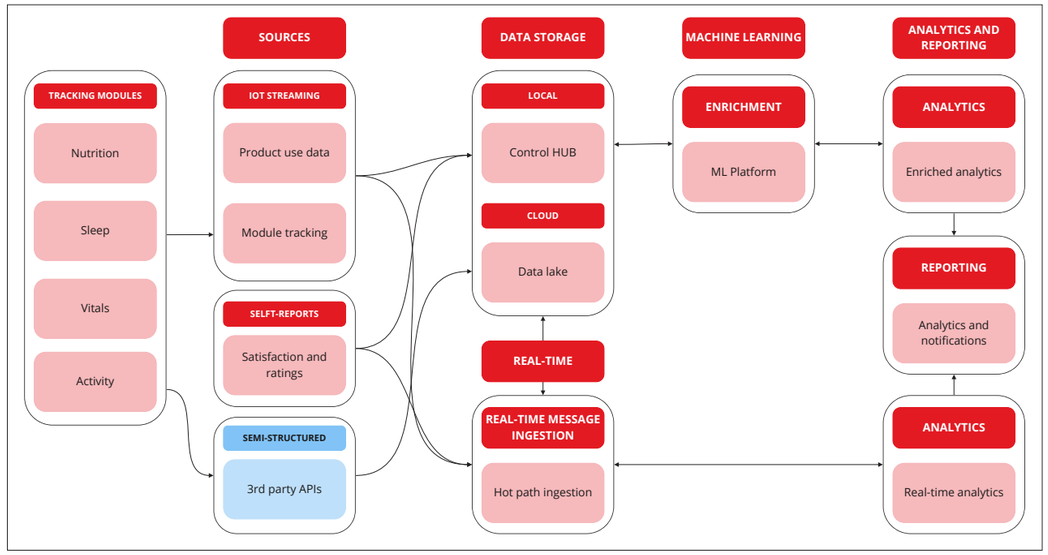


Figure 34. Deeper look at the data architecture.

The analysis and proposal of a high-level data architecture shown in Figure 33 seeks to bring light into what are the required hardware and software requirements for the system to operate. As the devices of Arçelik are expected to be the main sources and displays of information, they need to be connected to a field gateway in order to create a single data stream. This field gateway could be either a device of Arçelik, like a fridge with a screen, or a separate novel device with that as its single function. This field gateway would then be able to connect to the cloud gateway that would give access to processing and storage functions, resulting in reporting and notifications that would be sent back. The concept of the field gateway also allows some processing to occur on-site, with a part of it being meant to anonymize data and another to solve local scenarios like keeping stock of a pantry.

A deeper look into the data architecture shown in Figure 34 reveals the different

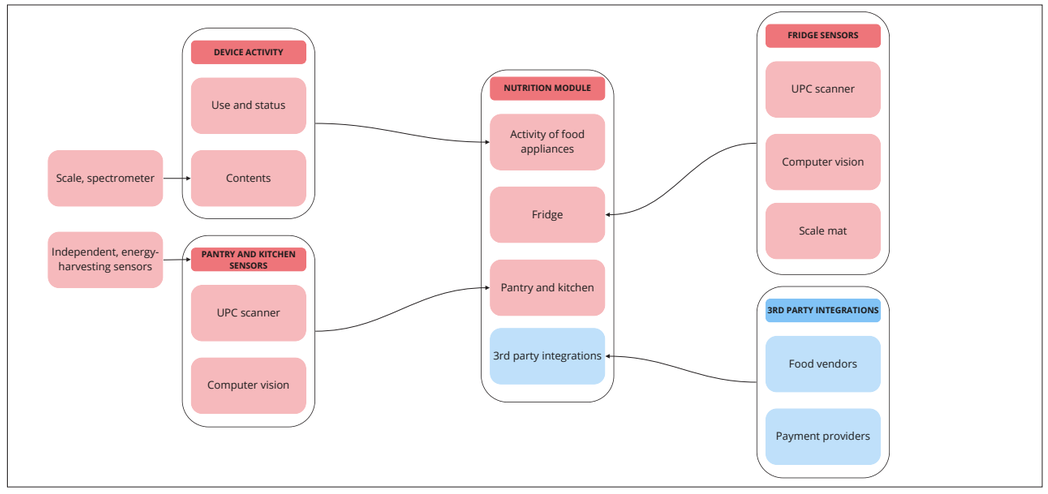


Figure 35. Data architecture of the nutrition module.

functions and how they align with each other. In this level, it is possible to see that the sources of information are not always Arçelik devices and will need a separate connection. By keeping third party devices separate, their varied accuracy can be better handled.

Each of the different modules receives information from several redundant sources. In Figure 35, the sources of the nutrition module are described. A redundant system allows arhealth to have a complete picture of the food products that are consumed by the user and allows for possible gaps of information without losing accuracy. In the example of the nutrition module, the food would be tracked by four redundant systems:

- Activity of food appliances (track what is used)
- Fridge sensors (track what is stored and used)
- Pantry and kitchen sensors (track what is stored)
- 3rd party integrations (track what is bought)

6.4 Concept validation

With the concept developed at an early stage, a round of validation with stakeholders and users was followed. The objective of the validation was to determine if the concept fits with the criteria set at the beginning of the brief and find its strengths and weaknesses when used with real users.

6.4.1 Stakeholder validation

The stakeholder validation session was framed around a presentation of the concept and aimed at gathering impressions, both at the product and system level but with more interest in the latter. The presentation was followed by a detailed discussion of the concept, focusing on gathering actionable insights that could lead to the refining of the solution in the next phase of the project.

The session was executed remotely and was attended by personnel of Arçelik with the titles Director of Industrial Design and Sr. Industrial Product Designer.

6.4.2 Results from the stakeholder validation

The result of the validation was positive, and it was decided to move forward with the project. Three important topics of discussion were followed during the session that had a relevant impact on the following testing and prototyping phases:

1. As the novelty of the system is not on its individual parts but instead on the combination of their capabilities, this requires at least two complete modules to be included in a first version of the service
2. For the following user evaluation, it is important to note what is meaningful and helpful to people and focus on that at the current moment instead of trying to do everything at once
3. The integration with 3rd party applications is very valuable to the scalability of the project and the expansion of the different modules, it is essential to be specific about what applications or systems arhealth will connect with

The first point is related to the main objective of the system to gather information from multiple sources and combine it to find relevant insights. With the exception of the nutrition module, these sources are proposed from 3rd party providers and not Arçelik products, and they rely on scale-proven recording methods comparable to clinically approved methods and recording mechanisms[62]. Considering this, the value of the system will only be fully appreciated when two independent modules have the necessary information to work together and combine information to deliver insights.

While the immediate implementation of the four modules would deliver a complete service that delivers the promises of the brief, such implementation would be highly unrealistic. As mentioned in Chapter 3, a strategy fit for Arçelik involves the slow buildup of novel capabilities in consumer products instead of a disruptive approach. The user evaluation is then an invaluable tool in the search for the characteristics of the system that are most relevant to users and it will be used to scope the current broad focus of the service and to serve as a guide during the implementation phase. The scoping that is expected to happen is located in the framing of the four tracking modules of the system and relating to two research questions: which tracking capabilities are the most relevant for the users and which capabilities are the absolute basic to build a Minimum Desirable Product[63]. The basis for this scoping will be the results of the user validation exercise, which in turn, will determine the 3rd party systems that will be used as sources.

6.4.3 User validation

The testing protocol for the user validation aims to understand the perceived value of an integrated passive sensing solution to users. Instead of presenting the concept and gaining a general perception like on the stakeholder validation, it is composed of a prototyped interaction based on the user logging their own data and then presenting it as if filled by the system. This process of personalization expects to bring a more personal perspective to the data that will be presented, and to get a more valuable insight of the value of such solution to individual users.

The question to be answered with the validation is "What is the perceived value of an automated logging solution?", separating such question in to activities that aim to understand the perceived value of the logging solution and the conclusions based on such logged data.

Two additional questions will be answered during the main process, each of them dealing with specific details of the system. The first one aims to understand the willingness of users to provide annotations to their logged data, by presenting different ways in which they can rate their food intake. The second one is focused on how users deal with incomplete or incorrect data by randomly altering details of their logs. When this data is presented to them, their reaction and response will be recorded as well as the mitigation actions that they take (if any).

Activities during the user validation

1. Survey about eating and activity habits- This quick survey looks to provide a baseline for the development of the personalized service solution to be presented in step 3, as well as providing basic demographic data for the filtering of the evaluation results.

Question	Activity	Duration	Reach	Prototype	Goal
What is the perceived value of an automated logging solution?	1 Have a cohort of users fill a questionnaire about their eating and activity habits	30 min	System	Trippeto chatbot	Provide a user baseline and basis for conclusions
	2 Have users log their daily intake of foods and activity in a supplied app	1 day	System	Logging interface in Glide	Have a baseline for manual logging
	3 Present the results as if logged in by the system, and explain how it did so	1 hour	System	Clickable prototype in XD	Understand the perceived value of an automatic solution
	4 Present a set of conclusions based on food intake and goals	1 hour	System	Clickable prototype in XD	Understand the perceived value of conclusions
How do users deal with small inaccuracies?	During activity 3 some data will be incorrect, log responses	-	Sensor accuracy	-	Learn the effect of inaccuracies in the system
Is the information users are willing to give enough to give meaningful conclusions?	During activity 2, users will be presented with different food rating options	-	Food rating	-	Test the value of filled data across users and rating styles

Figure 36. Overview of the validation protocol with users.

2. Log of daily intake of food and activities- This step provides the data that will be presented to users in the next step.
3. Presentation of gathered data in a mockup of arhealth- The data gathered in the previous step will be displayed to users in a wireframe and a walkthrough of the concept and its functions will be made.
4. Conclusions based on assumed and logged data- A set of conclusions will be presented to users based on the data provided by them at step 1 and 2.

Extra questions embedded in the activities

- During step 2 users will be randomly presented with different food rating options. This variation is aimed at finding the most valuable method of filling this information, balancing the hassle of providing highly annotated data with the limited value of a quick review.
- During step 3, some of the data that users logged will be modified and it will not accurately reflect their activities during the previous day. This will allow the evaluation to follow an example of how users deal with inaccuracies in the system.

Validation tools

The questionnaire was styled as a chatbot using an online tool. This delivers an engaging conversational experience while responding the questions and allowed the seamless use of conditionals. This is shown in Figure 37.

The logging system is provided as a web application build in Glide and shown in Figure 38, allowing each user to record their own activities and food intake while retaining full access to the information they fill. In screen two the different rating systems are shown, in the prototype provided to users they will rotate every time they fill the form showing one at a time. The options for rating food are: Feeling (emoji), Like (thumbs), Rating (5 stars), Rating (3 hearts) and I would buy it again (checkbox).

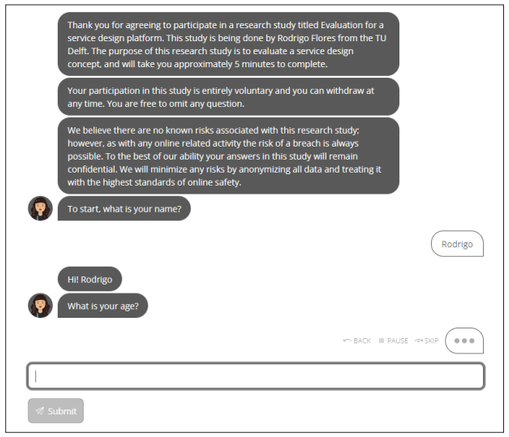


Figure 37. Questionnaire for the testing stylized as a chatbot.

Test run

The validation tools were tested with two different users in a supervised manner to find possible glitches or continuity issues. This was done as it would be better for the round of validation that the tools do not suffer changes and are presented in the same manner to the entire cohort of users.

- The constantly shifting rating element becomes confusing as it is not clear what is the comparison between different rating styles shown in different foods. Instead of offering a random rating element per record, a random rating element can be designed for each user and kept unchanged during their whole test. In some cases, a combination of two rating elements can be shown to each user instead of a single one.
- The ingredients input is the part of the form that requires the most time. This creates issues in the data logged as some ingredients will not be mentioned. Instead of ingredients, a picture input can be either added or replace the ingredients input. The effect of having a hassle-prone element is that it will likely increase the perceived advantage of an automated logging solution.

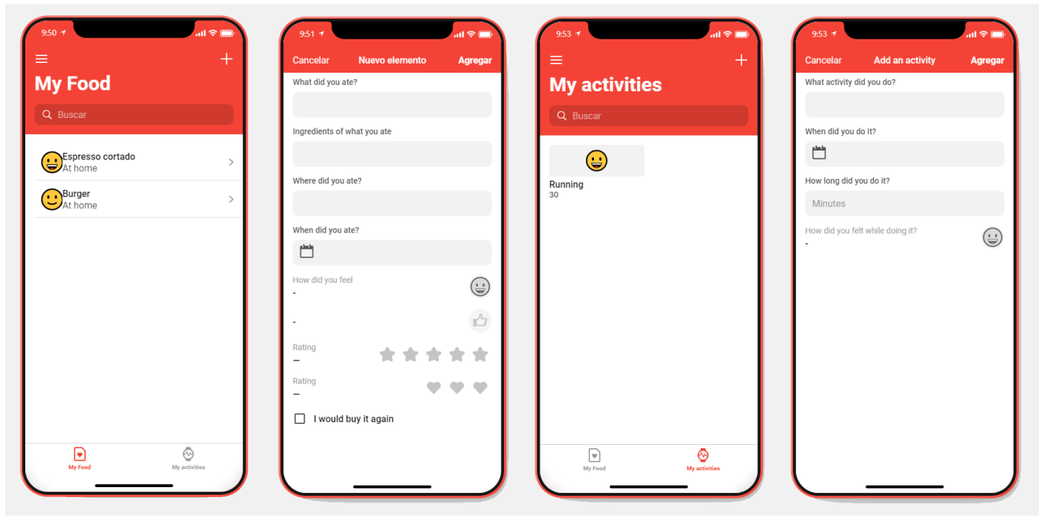


Figure 38. Web application to log activity and foot intake built on glide.

Sample

A total of 9 users took part in the evaluation, including the four that took part in the test run of the evaluation tools and were presented with the updated versions. Users ranged in age from 25 to 31 years old. All interviews were done remotely.

Users were asked to fulfill two characteristics, aimed at ensuring that the service would meet a potential user of Arçelik products:

1. Own or have bought at least 1 home appliance in the last year
2. Have 25 or more years

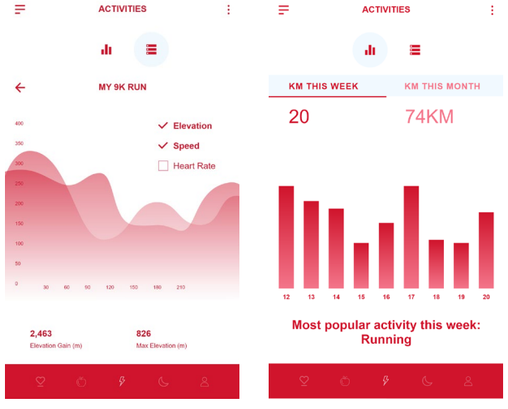


Figure 39. Clickable prototype.

6.4.4 Results from user validation

The result for the user validation was mostly positive, with users generally embracing the idea of using a service that would connect their devices and track their habits. Important insights were gathered from the resulting interviews and are ordered here by subject, followed by a list of potential changes to the concept.

Language of communication

Users felt that the communication given during the presentation of their advances towards their health goal could on itself be designed to encourage them to follow their health plan more seriously. Because the test just included a neutral statement regarding their adherence towards their health goal, it was generally felt that it lacked a human touch. This subject was raised with 3 out of the 9 users, and 1 of them also mentioned that the chatbot of Tool #1 showed a positive attitude that sounded encouraging.

Effects of reviewing recorded information

Some users experienced a negative emotion when presented with the overview of food that they ate during the logging procedure. Most of this discomfort was logged towards specific foods that they felt were not the best

choice or went directly against their health goal. The contrary was experienced with the recording of activity, as it mostly brought a sense of accomplishment in the users that recorded one.

Accuracy of caloric intake

The issue of accuracy in caloric intake was raised in over half of the interviews, with users commenting that, for example, a sandwich can have wildly different calorie counts depending on ingredients and unless you assembled it yourself it would be very hard to calculate this. While caloric intake was not part of the clickable prototype that was shown, it is a standard way in which food trackers work and it is then necessary to steer away the concept from quantitative to qualitative in a clear manner.

Privacy concerns

When explaining the different methods in which the system records information, questions were raised about cameras and privacy concerns. Most users agreed that the trust in the brand was a significant factor in choosing to buy a device with a privacy concern. The safe handling of all information was also mentioned, with users commenting that they would feel better if the data was encrypted or not uploaded to the cloud at all.

Integration with 3rd parties

While only 1 user already used a tool to track food, 7 out of 9 used or had used a tool to track their activity. Most of them preferred to keep using the tool they were using at the moment for different reasons, but would like the possibility of a seamless integration. The subject of the hassle of data not showing correctly or being delayed was mentioned as a hassle by them, and it felt like it diminished the accomplishment of completing a physical activity if it was not shown as soon as it was finished. As apps were mentioned as a potential pitfall for a smooth process, the integration with 3rd parties was also discussed when taking about compatibility with non-Arçelik devices and the possibility of having a kitchen equipped with devices from different brands.

Results from input methods

Of all input methods that were tested, the simpler method #4 “will you buy/consume again” was the preferred by users, as sometimes the complexity of rating a whole meal with a more complex quantitative method was not seen as objective or representative of their future behavior. An example of this is a food rating that could have been rated 3 out of 5 in #3 but would be repeated often because it is convenient. The similar rating style of the star versus the heart was also interpreted as very different and confusing, with both systems gathering a potentially different rating for the same food but providing very different information when asked why would they give a rating in one system and one in another.

Results from incorrect data

In order to test this, the list of ingredients on one food consumed the day before was edited. The change was subtle, and in some cases, it was not noted immediately and not at all in two cases. When discovered that the data was wrong, or told that it was, the question was raised by all users as to how the data could be edited after the system detects it. The subject of accuracy in logging came up again, with users wondering if the data would need to be reviewed often to look for inaccuracies and rising the issue of it becoming a hassle at some point.

Limitations of the tool

While the tools fulfilled its expected use, important limitations exist with the procedure that was taken and should be noted for further development.

A core limitation is that the tracking of two different modules was left out of this exercise due to a lack of means to gather data in a safe and consistent manner, meaning that the sleep and vitals modules were only presented as concept and not as part of the prototypes. While their value was presented to users and comments were extracted from this, it can be expected that as they did not experience it the importance, they regarded it was lower than those that they experienced.

Another limitation for the validation exercise was the lack of complete or actionable data from the users. This was shown mostly as incomplete lists of ingredients for the food tracking, or by skipping questions during the use of the first tool. The question about the health goals in particular was of high importance and was not filled by two users. Another was the understanding of the activity logging, as some users filled all physical activity that they did during the 24h period while others logged only planned exercising and not things like their bike ride to work.

Potential changes based on results

- Add an avatar or chatbot as a tool to control the system, allowing for a smoother integration with personal assistants and raising the possibility of controlling the system via voice only
- Food intake can be shown as a general overview based on food clusters and then as a list of ingredients, forgoing the idea of showing it as completed foods
- The best moment to confirm data is at the moment of consumption or use, when the system is in doubt about the logging of a certain element a confirmation could be raised to the user to confirm this information
- The method #4 “will you buy/consume again” provides the best quality of information out of users when annotating data, a follow up question can be asked if the result is unexpected

H1

2022

Growth of wellness capabilities

New smart capabilities
Inclusion of new characteristics on Arçelik devices.

Development of AI models

1.0 Nutrition module
Introduction of nutrition module and arhealth.

2024

H2

Focus on FDA and CE approvals

3.0 Sleep module
Offer full in-house products.

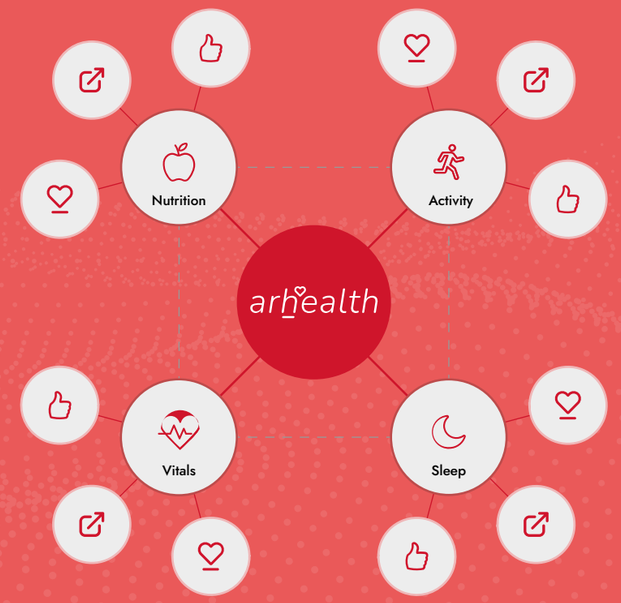
2.0 Activity module
With the development of new products.

2026

H3

Offer a complete ecosystem of health

Arhealth 4.0 launched
With all four integrated modules.



The arhealth modules at H3

The arhealth ecosystem

arhealth

Roadmap towards a new future vision.

Figure 40. Design roadmap.

Chapter 7:

Project conclusion.

7 Project conclusion

This chapter presents a conclusion and discussion of the project, including recommendations for the future application of learnings and a personal reflection on the process that was followed.

7.1 Recommendations for the project

Scoping the features

When discussing the project, the broad approach of the concept was a subject that came about often. The validation part looked for evidence to reduce this scope and allow for a tighter approach, but still the project is composed of four different modules. A good recommendation for the future of the project is to scope down these four modules, and make a clear selection of features that are basic for the product to work.

Integrate with pipeline of products

With the increase in smart capabilities in the products of Arçelik, some of the required technologies for this project will begin to be used for other purposes. By having access to the development pipeline of the company, an accurate time pacing strategy can be achieved.

Entry into healthcare

A decision that Arçelik will need to take in the close future is to clarify the intent they have with their entry into the healthcare market. Another project might look at this on its own, and could provide strategic recommendations into the value of entering such market.

7.2 Discussion and limitations

Changes in direction and scoping

This project started with a search for opportunities in the area of e-health, and most of the contextual research shows this wide exploration. While this research was very valuable to the project, and to the individual development of the author, it meant that a lot of time was dedicated researching things that would be of limited or of no use in the end concept. This, however, provided not the concept, but the strategy behind it, with a high degree of validity. This is because the research into, for example IoT medical devices and later the research into the company, grounds the opinions of the design personnel into not exploring strict healthcare as a business opportunity in this moment. While this seems contradictory to the medical products that the company has launched in the last few years, it is not, as they were produced at great expense, always with an external partner and without commercial presence or success. This line of thinking that is part of the organizational strategy is not an embargo on the development of medical concepts within the company, but rather, an acceptance on the limitations and the search for creative avenues to overcome these limitations.

Limitations with user research and validation

During the course of the project several different strategies to test the concept were discussed, but testing the concept was harder than expected due to the required fidelity of the tools to receive the expected results. On the concept stage, it is easy to get a quick yes from people, specially when the concept is futuristic and is not similar to things the interviewees have tried before. Being honest about the perceived shortcomings of the project is also a difficult road, as it means to begin the validation from a negative standing. In the end, the validation process found a compromise in using personal information to enhance the prototype application so it felt more functional and less static. The results, still, no not fully validate the concept, as the high complexity of it would mean a highly complex validation process. The compromise taken meant that a single module was validated, and while it shows promise in the use of the full concept, it will require further work.

Technological assumptions

The concept makes use of state-of-the-art technology in its proposal, and does not get into the details as to how these technologies will be applied or developed. This high degree of uncertainty about the assumptions makes them risky, as the developments that are needed for this concept to work as intended do not exist yet. The justification for keeping those assumptions is that they are being developed, and many companies are having significant success in applying them in a limited manner. The use of AI in this project is kept very general, as the specific workings of this system are not a part of the scope of the project, but because of this they become part of the list of risky assumptions.

7.3 Personal reflection

As a closing of this project, I have written a personal reflection organized on a series of topics I find worthy of writing about.

Limitations in contact

Working in a project during the pandemic meant a limiting scenario from the start. While I had the luck to meet with my TUD mentor in-person a few times in the faculty, the same did not occur with my TUD chair or company mentor. While this limiting scenario was something known since the beginning, I firmly believe that the work of a designer is that of working with people for people, and I am now aware that I should have looked for further opportunities to meet with my graduation committee and other experts in person. My way around this was to look for a lot of people to interview and talk about the project in general, and get my head filled with information so I was always thinking about it. Sometimes, however, this constant thinking meant an overflow of information and it did more damage than good.

Performance and clarity of mind

This overwork part was difficult to handle for me at first, as I found myself during the summer working every day and spending my weekends in the university working in the project. Balance became a relevant topic for me because I was getting drifted into an always active state of mind, and even when I had the chance to relax, I did not. I finally found ways to regain this balance by keeping a clearer track of the work I was doing and the work I wanted to do, and estimating how much time that would take and fitting that into a schedule that allowed me to do the things that made me feel good. Indeed, I found my own path to wellness in this project.

Positivity

Working in a context in which bad outcomes mean great harm was distressing at moments. During the course of my research, I read books and papers that greatly influenced the way I thought about certain subjects like mortality and disease, and provided insights into how to tackle them but also accept them. This is said of course in the context of medical practice, of which I am not a part of, but as a designer the same outcomes need to be accepted as well. In the course of the project there were times in which I encountered an impassable barrier, and accepting that became one of my biggest learnings. I found that even the way I talked about these shortcomings changed, from a negative stance to a rather positive and aware stance. In the book “Better: A Surgeon’s Notes on Performance”, Atul Gawande comments a similar behavior in doctors, and suggests that instead of letting the natural pull of gravity led you to “the litany of woes all around us”, you should resist it and instead use this opportunity to discuss and idea or opportunity.

My personal ambitions

Reviewing now the personal ambitions that I wrote in the beginning of the project; I am happy to say that I have work hard towards them and have made the advances I consider as successful. Talking with other researchers the subject of when to stop a project always comes up. I am sure that if I had a week more, or a month, or a year, this project could have been much better. But considering the limitations that a graduation has, those I imposed on me and those that I could not control, I am happy with the quality of the deliverables I have finished. The same goes with my ambitions, that upon reviewing I notice are very broad, but that nevertheless allowed me to explore a topic I truly enjoyed and that I will keep enjoying in my next challenge.

Chapter 8:

Abbreviations and references.

8.1 List of abbreviations

- BVM - Bag-valve-mask
- CDC – Center for Disease Control
- CE – Conformité Européenne
- COVID19 – Coronavirus disease 2019
- CVD – Cardiovascular diseases
- ECG/EKG – Electrocardiogram
- EHR – Electronic health record
- EUA – Emergency Use Authorization
- EUA – Emergency use authorization
- FDA – Federal Drug Administration
- GP – General practitioner
- ICT – Information and communication technologies
- ICU – Intensive care unit
- IoT – Internet of things
- LUMC – Leiden University Medical Center
- MDD – Medical Device Directives
- MHRA – Medicines and Healthcare Products Regulatory Agency
- PPE – Personal protection equipment
- R&D – Research and Development
- WHO – World Health Organization

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