**Design project
M1.1**

VoetZie

A diabetic feet scope

Technology support for diabetes

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Subject

Design for people with diabetic feet

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Abstract

People with diabetes have the risk of developing neuropathy that can lead to reduced feeling in their feet. That condition, called diabetic feet, can lead to the development of wounds that can go initially unnoticed, are difficult to treat, and could even lead to an amputation.

The best way of prevention is checking patients' feet on a regular basis. However, some of them do not understand which signs they should look for nor the risks involved. The goal of the project is thus to increase patients' awareness about the benefits of prevention and the potential risks of not taking proper care of their feet.

The design process involved medical experts in different stages providing insights and evaluative feedback through interviews and co-design sessions.
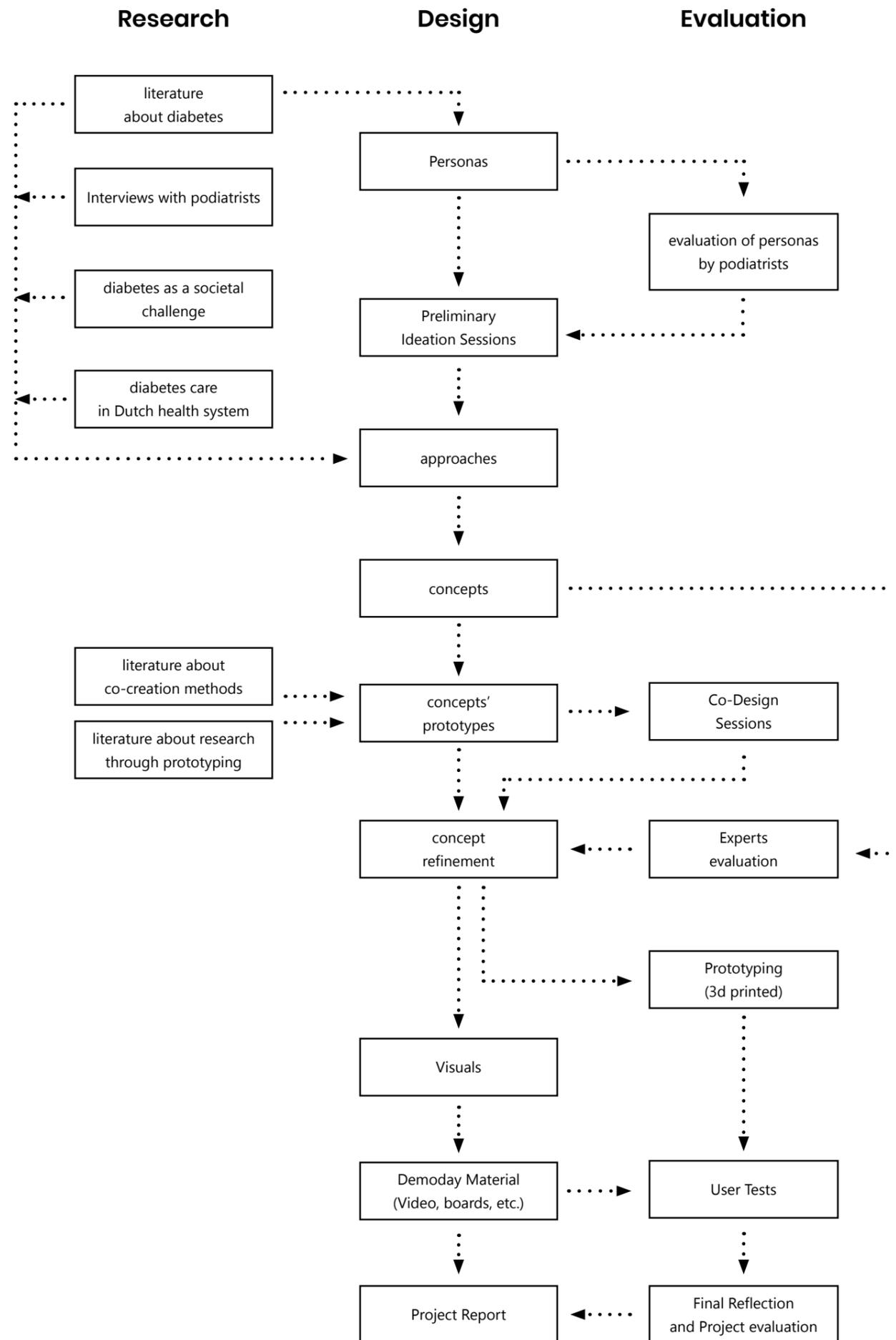
As a conceptual project, VoetZie uses Augmented Reality (AR) technology to enable podiatrists to show patients initial warning signs projected on their own feet. That way, it aims to provide a better understanding and raise their awareness about complications with the aid of a visual and direct approach.

A video demonstrating how the concept works was presented to patients and podiatrists for feedback. Recommendations for future developments were included in the final session of this report.

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Process timeline

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Introduction

Diabetes is one of the world's most prevalent chronic diseases. In 2017, about 425 million people worldwide had diabetes, representing globally approximately 8.3% of the adult population (Whiting et al., 2011). It is expected the number of people with diabetes will be increasing very rapidly. For instance, the number of people with diabetes mellitus rose from 0.4 million in 2000 to 0.8 million in 2011 and is expected to be around 1.2 million by 2030 (RIVM, 2014).

A common debilitating complication of diabetes is developing 'ulceration of the foot'. The complications of having such feet are mainly due to the presence of different grades of ischemia, and peripheral neuropathy (Jeffcoate, 1993). As a result, these ulcer symptoms will significantly increase the risk for further infection and might eventually cause amputation, because of non-healing foot ulcers. This covers a remarkable number of 85% of all diabetic amputations (Apelqvist et al., 1995). Ultimately, such complications may increase pressure on health and social security systems as people in those conditions can no longer work or may need special assistance (World Health Organization, 2016).

Previous work has demonstrated that diabetes self-management is cost-effective and can prevent both hospital admissions and the development of complications in patients with diabetes (Healy et al., 2013; Robbins et al., 2008; Shelton Brown et al., 2012). For this to be effective, however, it is important to educate patients about self-care behaviour and the risks involved in not handling their condition properly (Powers et al., 2020; Shin & Lee, 2018).

RondOm Podotherapeuten has developed a self-management application for people with diabetes and foot complications called the ''Diabetes Voetencheck app''. It focuses on a regular e-screening of the foot and sends daily push-messages to patients to check their feet. By asking interactive questions the app guides them through the procedure and depending on the answers, the patient may be asked to take a picture of their feet. This picture will be sent to a podiatrist, who will determine if any further treatment is necessary (Fontys Paramedische Hogeschool & Lectoraat Health Innovations & Technology, 2020)

The pilot launch of the app was quite successful helping patients to prevent wounds that could have evolved to serious complications. However, some of them still do not understand which signs they should look for nor the risks involved. The goal of the project is thus to increase patients' awareness about the benefits of prevention and the potential risks of not taking proper care of their feet. The design process involved medical experts in different stages providing insights and evaluative feedback through interviews and co-design sessions.

As a conceptual project, VoetZie aims to provide a better understanding and raise patients' awareness about the risks of developing diabetic feet with the aid of a visual and direct approach. With the aid of technology it enables podiatrists to show patients initial warning signs projected on their own feet during an appointment.

This report starts with the Problem definition, where relevant information is presented about research, findings and the arguments used when building reasoning. Design Process brings an overview of the activities that lead to the Final Concept that is followed by its evaluation after Demo day. Discussion examines the limitations of this project, its impact on results, and leads to Conclusion and recommendations for Future Work.

Problem definition

The problem was approached from different angles to explore possibilities and search for design opportunities. Initially, five semi-structured interviews were conducted with podiatrists for a broad comprehension of the topic. Then, thematic analysis (appendix 1) of data was combined with literature research to frame the project scope, define the target group and formulate a problem statement.

Evolution of a patient with diabetes

Initially, people diagnosed with diabetes visit the general practitioner or practice nurse for a yearly examination of their feet. That evaluation will determine a 'Sims classification' (see figure 1), with four levels that indicate the stage of feet problems for people with diabetes (Provoet, 2018). This model is used to decide what care is needed for the patient. (Voetencentrum Wender, 2021) Whenever 'Sims classification 1' or higher is established, the patient must visit a podiatrist (Provoet, 2018). That professional will carefully inspect the feet, looking at their position, walking patterns, pressure points, blood flow, and general sensibility levels (see appendix 2 for transcripts). This aims to estimate the level of risks associated with a patient's condition and helps podiatrists to determine a 'zorgprofiel' that indicates necessary care to limit those risks and determine compensation (Voetencentrum Wender, 2021).

Sims Classification	Zorgprofiel
Classification 0 No decreased sensation or decreased blood flow in the feet.	**No Care Profile** Sims 0, other wounds, active Charcot foot.
Classification 1 Decreased sensation or decreased blood flow.	**Care Profile 1** This is *Sims Classification 1* and it does not matter whether you are able to care for yourself.
	Care profile 2 There is *Sims classification 1* and there is an increased risk of skin damage, infections and/or pressure sores. Or There is talk of *Sims classification* 2 and there is reduced feeling in the feet and reduced blood flow.
Classification 2 Decreased sensation and decreased blood flow. or Decreased feeling, decreased blood flow and pressure sores.	**Care profile 3** There is *Sims classification 2*, there is reduced feeling in the feet, reduced blood flow and pressure spots are present.
Classification 3 A past foot injury or amputation in the past. Or Inactive Charcot Foot, End Stage Renal Failure, or Renal Replacement Therapy (dialysis).	**Care profile 4** There is *Sims classification 3*, there has been a foot injury in the past or an amputation has taken place. Or There is an inactive Charcot foot or renal replacement therapy (dialysis).

Figure 1: Sims classification and zorgprofiel

The importance of checking feet

Podiatrists interviewed for this project indicated that there are two main factors that lead to the development of diabetic feet. First is neuropathy, which means patients lose the sense in their feet because the superficial skin nerves do not work anymore. As a result, they do not feel that they are developing wounds (appendix 2). The second one is that the patient's blood flow deteriorates, because of bad nutrition and a high cholesterol level. For that reason, wounds on their feet do not heal easily and need careful treatment (appendix 2).

One of the most effective ways patients can prevent complications is by scanning their feet frequently (Nederlandse Vereniging van Podotherapeuten, 2019). This means performing a self-inspection in search of preliminary signs of wounds or any evidence of a risk-increasing situation. It should be done on a daily basis outside the appointments along with other routines recommended by the podiatrist. When treatment is successful, there is even a possibility to lower 'het zorgprofiel' (appendix 2).

Current problems and their impact

Thematic analysis of transcribed interviews revealed the following topics that could be later explored and lead to design opportunities:
- Low standards for self-care and associated problems;
- Health illiteracy and therefore lack of understanding of risks;
- Not checking feet with the necessary frequency;
- Incapacity to relate to the diabetic condition.

Although being described as a diverse group (appendix 2), people with diabetic feet share commonalities as most of them are not able to take good care of themselves. Besides, they usually also struggle with other problems, such as depression and being overweight (appendix 2).

Another problem is that they do not understand the importance of checking their feet before they have any wounds. Prevention is crucial, but most patients are not able to link it to the risks (appendix 2). Also, patients may have completely lost sensibility in lower limbs, hence might not notice wounds inflicted by sharp objects that could evolve to a serious condition (appendix 2).

One podiatrist also mentioned patients who do not take care of themselves and do not take their own health seriously. She gave an example of a patient that has already lost one leg, developed wounds on his other foot but still can not see the importance of visiting the doctor (appendix 2).

''*The effectiveness of diabetes management ultimately depends on people's compliance with recommendations and treatment. Patient education is, therefore, an important component of diabetes management. Patients need to understand the principles and importance of a healthy diet, adequate physical activity, avoidance of tobacco and harmful use of alcohol, adherence to medication, foot hygiene and appropriate footwear, and the need for periodic assessment of metabolic control and the presence or progression of complications*''

– World Health Organization, 2016, pp. 51

Target group

The definition of a scope for the project required a specific target group to be focused on. A range was determined using a timeline created based on information available on WHO's website (WHO, 2016) and on brochures by Dutch associations of podiatrists and diabetes care (Nederlandse Vereniging van Podotherapeuten, 2019). It shows a possible scenario for the evolution of a patient's condition, from diagnosis to possible amputation of a limber. The target group was then defined as people diagnosed with diabetes, who started to develop diabetic feet but have not yet presented wounds (see figure 2).

Figure 2: Timeline diabetes

This decision was based on the following criteria:

- Focus on a product/service that people with diabetes can relate to (stimulate engagement);
- Acting BEFORE patients would evolve to a more serious condition;
- Stimulate people to properly manage diabetes and its possible complications.

Patients with diabetes usually suffer from other associated conditions, such as psychological issues and social stigmatization which make them hard to reach and engage with (appendix 2). Solutions can be more effective if acting before patients develop wounds, as the risk of recurrence after developing foot ulcers is highly increased (Apelqvist et al., 1995). This can be achieved by helping patients understand the risks, the importance of self-care, and therefore, frequently scanning their feet (World Health Organization, 2013).

Matrix

Two main aspects were mentioned by podiatrists as having an influence on a patient's evolution: how aware they are about the risks of developing diabetic feet and their interest in self-care (appendix 2). The target group was then classified in a matrix based on these two axes, and clustered into four zones, each of them suitable for a different kind of concept. See figure 3 on the right.
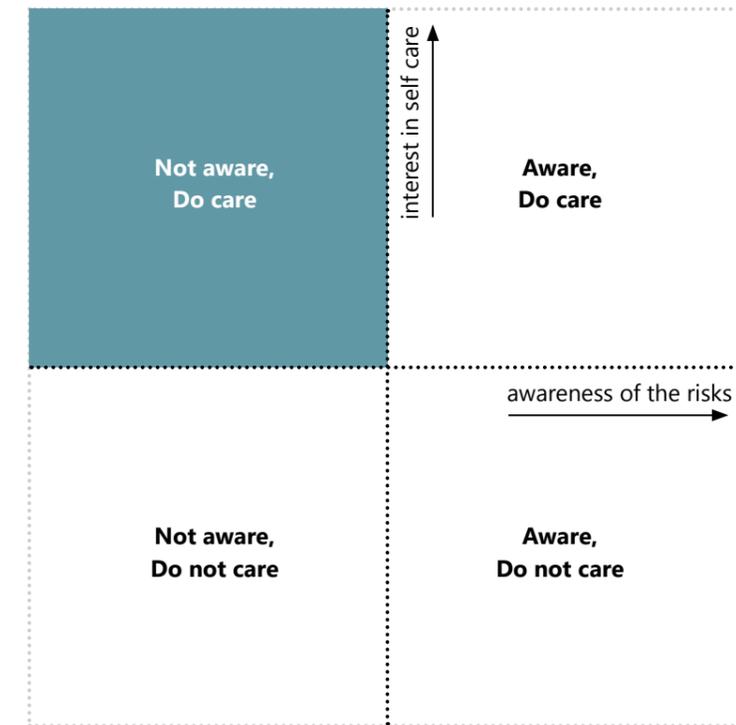
Figure 3: Aware-care matrix

A decision was then made to focus on the top left cluster, considering the following criteria:
- concerns expressed by interviewed podiatrists;
- potential benefits for patients allocated in other clusters;
- project's time constraints;

Four of five podiatrists interviewed expressed concerns about the general lack of awareness about the risks of diabetic feet. Three of them mentioned efforts towards trying to educate patients and the search for more effective ways to make them understand how serious it might become (appendix 2). Interviews also indicated that concepts created to educate and raise awareness could also benefit patients in other clusters, even though they were not their primary target.

Problem Statement

Research and interviews demonstrated that an effective solution could only be achieved by stimulating patients and podiatrists to work together in a complementary way (Provoet, 2018; appendix 2). First, patients need to understand the impact of their behaviour on their feet health (appendix 2). Then it is important for them to know how to check their feet and what could happen if they do not do it properly (appendix 2). On the other hand, podiatrists need to make sure that their patients are fully committed to the task and behaving according to recommendations (appendix 2). Also, patients would be able to rest assured that they are doing what they need to do in a proper way and that they will be contacted immediately if anything goes out off track (appendix 2).

Considering those different perspectives, from the main users of the future solution - patients and podiatrists - and also for the project's client, the design challenge was defined as it follows:

"How can a design aid in stimulating necessary behaviour to prevent people with diabetic feet from developing wounds?"

Design process

Personas

It was not possible to interview patients at the first stage of the design process, therefore personas (see figure 4) were created to get to know the target group. The personas were set up based on the first conversation with the director of RondOm Podotherapeuten and literature research. During interviews with podiatrists, these personas were discussed for confirmation. After the interviews, the personas were adjusted and finalized. Three personas were created, two patients and one caregiver. Each persona shows their living situation, background information, diagnosis, and mental and physical health stages (appendix 3).

Figure 4: Personas

Preliminary ideation

In parallel with research about the problem and target group, several ideation rounds were done following the 635 method (figure 5), moodboards, brainstorming together and individual sketching (appendix 4). These ideation sessions resulted in ideas that could be divided into three approaches: sharing, showing, and reasoning. With these three directions in mind, a new round of ideation started.
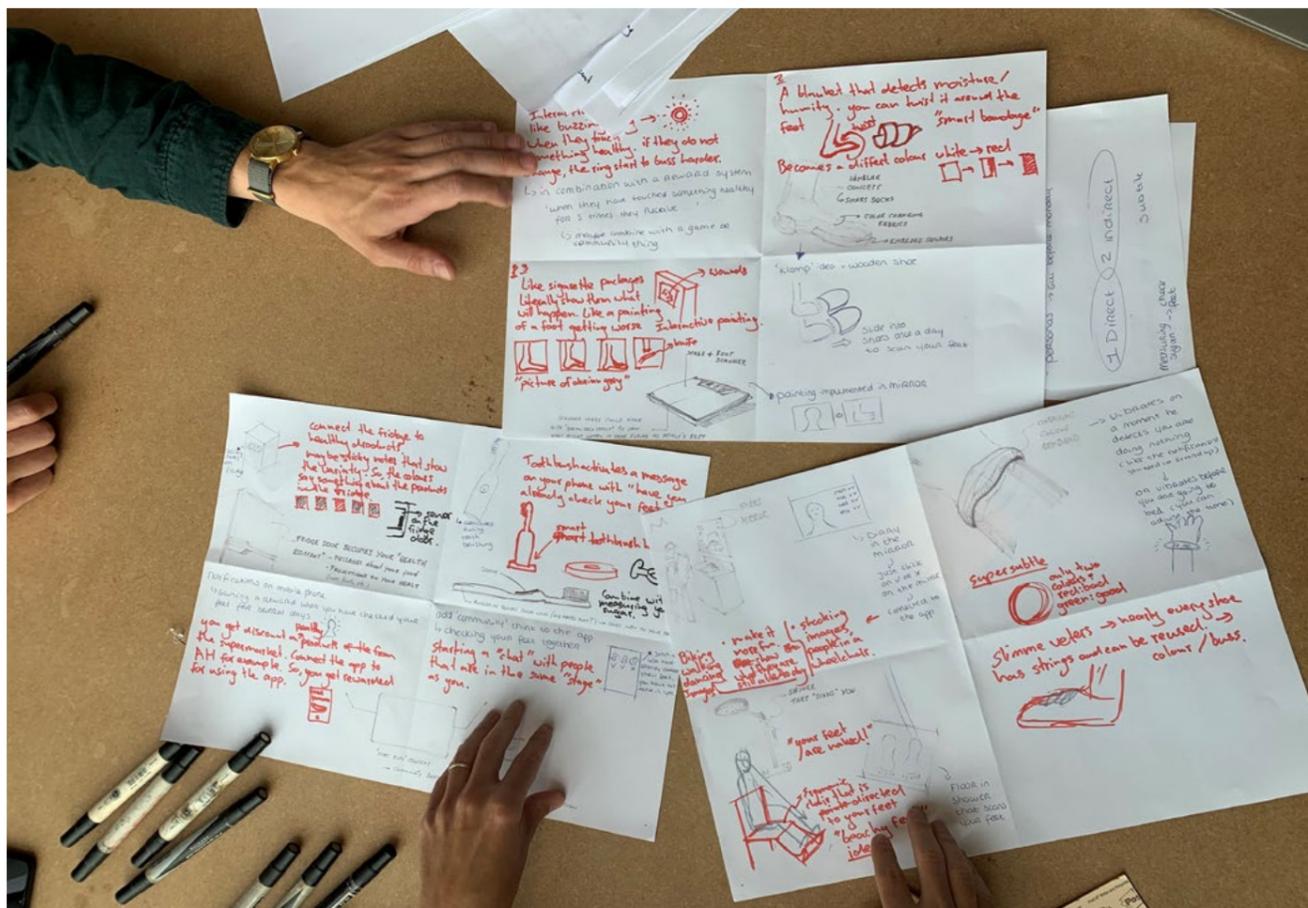

Figure 5: 635 method session

Approaches

Sharing

The first concept is based on creating a tool to share the knowledge of the patient among the other patients. This does not have to be a community in particular, but a platform for people with diabetic feet to share their own experiences and habits. Based on the fact that the psychological relatedness of values affects the persuasiveness of the arguments that bind them it is most likely that people with the same complications are more willing to listen to each other (Maio et al., 2014). This can also be seen in similar patient groups like people with dementia, where Alzheimer Nederland developed the so-called Alzheimer Café. A public place where fellow allies come together, get informed about dementia, and can share their ideas and experiences about their complications (Alzheimer Nederland, n.d.). Unfortunately, the concept of having a physical community does not exist for people with diabetic feet. If there is no physical community around people with diabetic feet, how can people with diabetic feet be stimulated to share their personal experiences with diabetes? This question led to the idea of using the environment of the practice waiting room, a public space where patients have to wait once in a while. Because the patients will be on the same spot, but not necessary at the same time, it creates the opportunity to build something together with people with the same condition without directly seeing or knowing each other or having to be digitally literate. Based on the idea of designing something that transforms over time it was clear the concept needed to be an aesthetically attractive object, be respectful to the personality of the user, have a low-threshold and attractive interaction, create a community feeling.

Showing

The second is a more direct approach, where the podiatrist shows the patient potential consequences to the patients during an appointment. This concept can be seen as a supportive tool for the podiatrist. By showing the patient a potential future perspective the patient gets a better understanding of the severeness of the problem. This approach might feel a bit drastic, but might be the right eye-opener for the people that do care about their feet. Therefore, it is worth mentioning that showing graphic complications might lead to the opposite reaction. Some studies for example suggest that graphic warning labels may prompt defensive reactions in smokers that cause warnings and messages to have a contra-effect of what is intended (Shadel, et al., 2019).

On the other hand, the difference between a graphic warning label on a cigarette package and showing graphical content to a diabetic patient is the fact a podiatrist is involved that has the expertise and knowledge of the patient to determine to what graphical level the patient needs or can be exposed.

Reasoning

The last approach is reasoning and focused on making the patient more aware through gamification. An educational tool for the patient and a supportive tool to help the podiatrist motivate the patient. This indirect approach asks the patient to make decisions playfully based on their habits. The strength of this approach is to build up to a moment where the patient comes to understand, a moment of surprise, or a moment of no return. A game that is played by the player's perception of diabetic feet. The patient's level of awareness and their related choices determine how the game will go. The game will give the patient time to reflect on their complications. The game also shows the patient it is not too late to change their behaviour and clarifies why changes have to be made.

Concepts

Concept 1: Message in the Bottle (sharing approach)

People happen to feel the urge to leave something behind and get something in return, like; comments online, an opinion, a message, or something they wish for. A few examples are the well-known wailing wall in Israel (see figure 6), which refers to the practice of putting pieces of paper containing written prayers to god into the cracks of the wall (Holy Land Tours Travel, n.d.). Or the so-called love locks in Paris to seal the infinite love (see figure 7). The similarity of both of these examples is that it is done by multiple individuals that do not particularly know each other but come together at a specific spot to interact with the same object to an extent the object (for example the wall or fence) becomes something completely new; different aesthetics and an enriched purpose. This aspect of giving something and receiving something back that transforms over time leads to the following concept; message in the bottle.

"Message in the bottle" is an object that stimulates engagement between patients that share the same condition through a give and receive interaction.

The prototype is designed to prove the give-receive concept within the context of a practice waiting room. To make it more understandable for the experts and to determine if this would be realistic and feasible the prototype is validated through a co-design session. The final prototype is a very minimalistic design, without any serious regard to aesthetic attraction; a solid block with multiple holes on two sides that function as an input-output system. Each hole is packed with one glass bottle that can be filled with a written note. Empty notes can be found on top of the block, together with a pencil (see figure 8).

The idea behind this system is to see whether people are being attracted by the action of writing and reflecting about/on their own experience and sharing /giving this to other strangers and receiving other written notes in return. In other words, the participant trades one personal note with one random note. This is interesting because it shows if someone takes those actions/steps in the first place, but also their capability to emphasise and imagine someone else's experience or story.

It is worth mentioning that the prototype used in the co-design session was still very plain, which overshadowed the potential it had. Namely, something with a more tuned and attractive interaction between the patient and object. A good example is the fictional ''tree of voices'' from the movie Avatar (see figure 9). The tree is named after this because the ''voices'' of ancestors could be ''heard'' by having close physical contact with the tree (Avatar Wiki, n.d.). In other words, the more attracted and closer you are to the object the more you get in return.

Figure 6,7,9 : Wailing wall (screenshot Youtube), Paris padlocks (photographer unknown), Avatar (screenshot Movie)

Figure 8: prototype- Message In A Bottle

Concept 2: AR Lens (showing approach)

The second concept is the Augmented Reality Lens; a tool that enriches the patient's perception of diabetic feet complications. The AR Lens uses modern technology to virtually display possible complications on the patient's real-life feet. It is like a magnifying glass with a smart twist. Compared to the other concept this concept has a much more straightforward approach.

AR is a fast-growing area of technology, a rising tendency amongst businesses convoluted in business applications and mobile computing, which also applies to Healthcare as well. According to a study by Boshale (2021), '' AR technology could lead to people becoming more reliant on devices that may source a large amount of health-related matters" (p. 61) . Although, within the field of treating diabetic feet it is still quite unknown. Therefore, designing an AR system can add a lot of value to the communicative relation between patients and podiatrists.

How does it work? The podiatrist aims the lens on the feet of the patient and highlights different aspects of the foot that are already there. When this happens both the podiatrist and the patient see the same visual. This makes it easier for the podiatrist to explain to the patient what complications need to require some extra attention. The AR Lens has the option to create a future perspective of the feet by creating a layer/filter on top of the patient's feet that shows different complications that eventually ''could'' happen.

Because the concept contains a lot of high-tech technology the initial prototype was worked out on a very conceptual level; a plexiglass screen connected to two wooden handles (see figure 10). The goal for this prototype was more focused on evaluating how an expert would act with a device like this within the context of practice, rather than evaluating the technical feasibility or possibilities within the concept.
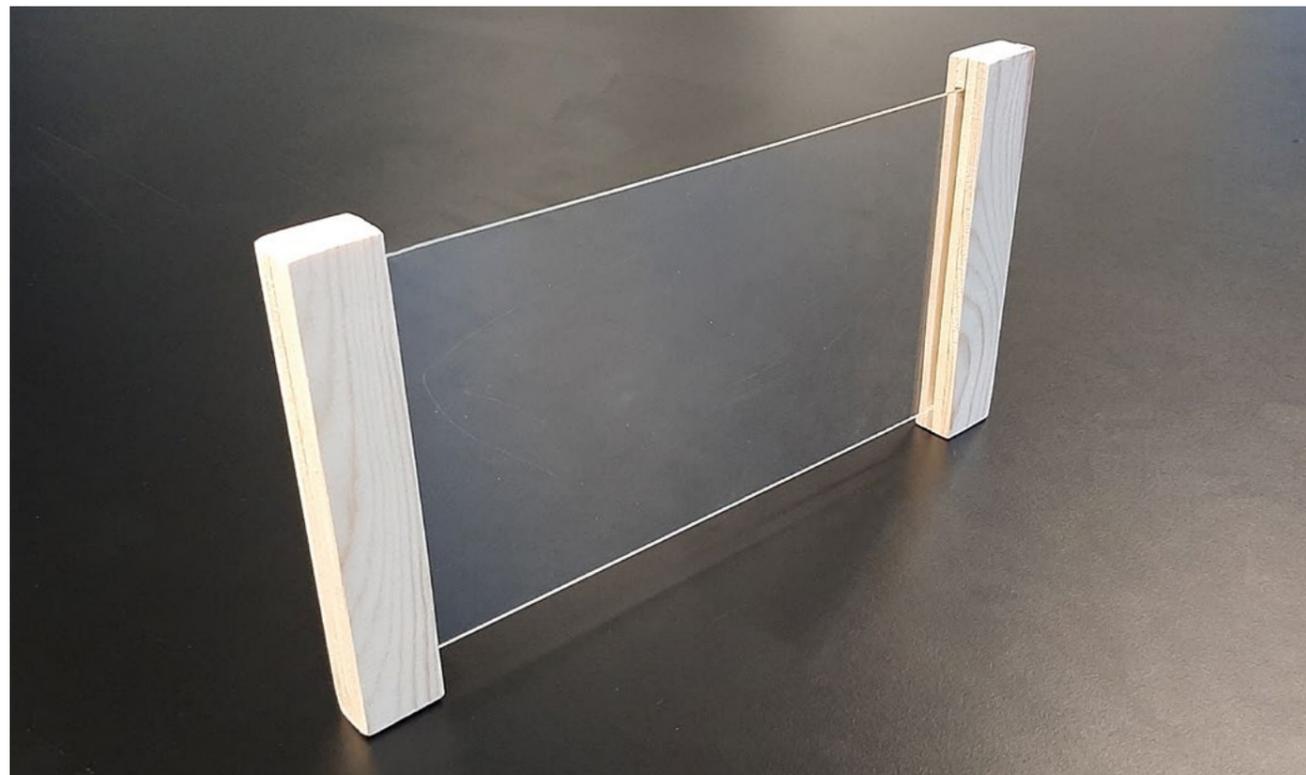

Figure 10: prototype-AR Lens

Concept 3: Educational gamification (Evaluation approach)

The main idea of the last concept was to create a metaphorical puzzle that visualised the impact of changes through time, where the late changes have a smaller impact than one of earlier stages. This puzzle shows the patient that it is not a problem to make mistakes, but emphasises that decisions lead to consequences and can become a problem when you keep making mistakes. In other words, this puzzle creates a feeling of being

Concepts Evaluation

Experts Evaluation

A review with experts, the director of RondOm Podotherapeuten and project leader of Team 'Technology Support for Diabetes', was done to receive feedback on the concepts. Several conclusions came out of this discussion (table 1) that were considered in the final concept decision. The confirmation of the approaches was based on four aspects (appendix 5):

Sharing approach	Showing approach	Reasoning approach
This approach might be too complex for the target group. Besides that, it could be risky when nobody supervises which messages are written down because patients could give wrong advice to each other.	The experts considered this approach the most promising. They are sure that this will help to create awareness about the risks of diabetic feet. This approach could be combined with the already existing application and could be applicable for all target groups within the matrix.	This approach could be combined with an already existing technique that podiatrists use during their appointment: motivational interviewing. However, this approach might be too hard to implement in the appointment, since there is no time for that.

Table 1: Conclusion for each approach

After this review, it was also decided to not involve patients in this stage of the design process. According to the director of RondOm Podotherapeuten, showing (low fidelity) prototypes to patients would not lead to useful information.

Co-design sessions

After the expert's evaluation, it was chosen to only focus on two approaches, to be prototyped: the sharing and showing approaches (see concepts). These were used during a co-design session with podiatry students of Fontys Hogeschool (see figure 11, 12) held to validate them and collaboratively find new solutions and possible flaws from an expert perspective (Zamanopoulos & Alexiou, 2018). The results and insights of the co-design session can be found in appendix 6.

A SWOT analysis of the resulting data led to the conclusion that either approach (sharing and showing) had the potential to continue during the project. Both presented some flaws and room for improvement, although the "message in a bottle" concept had issues that could not be addressed within the timeframe of this design project.
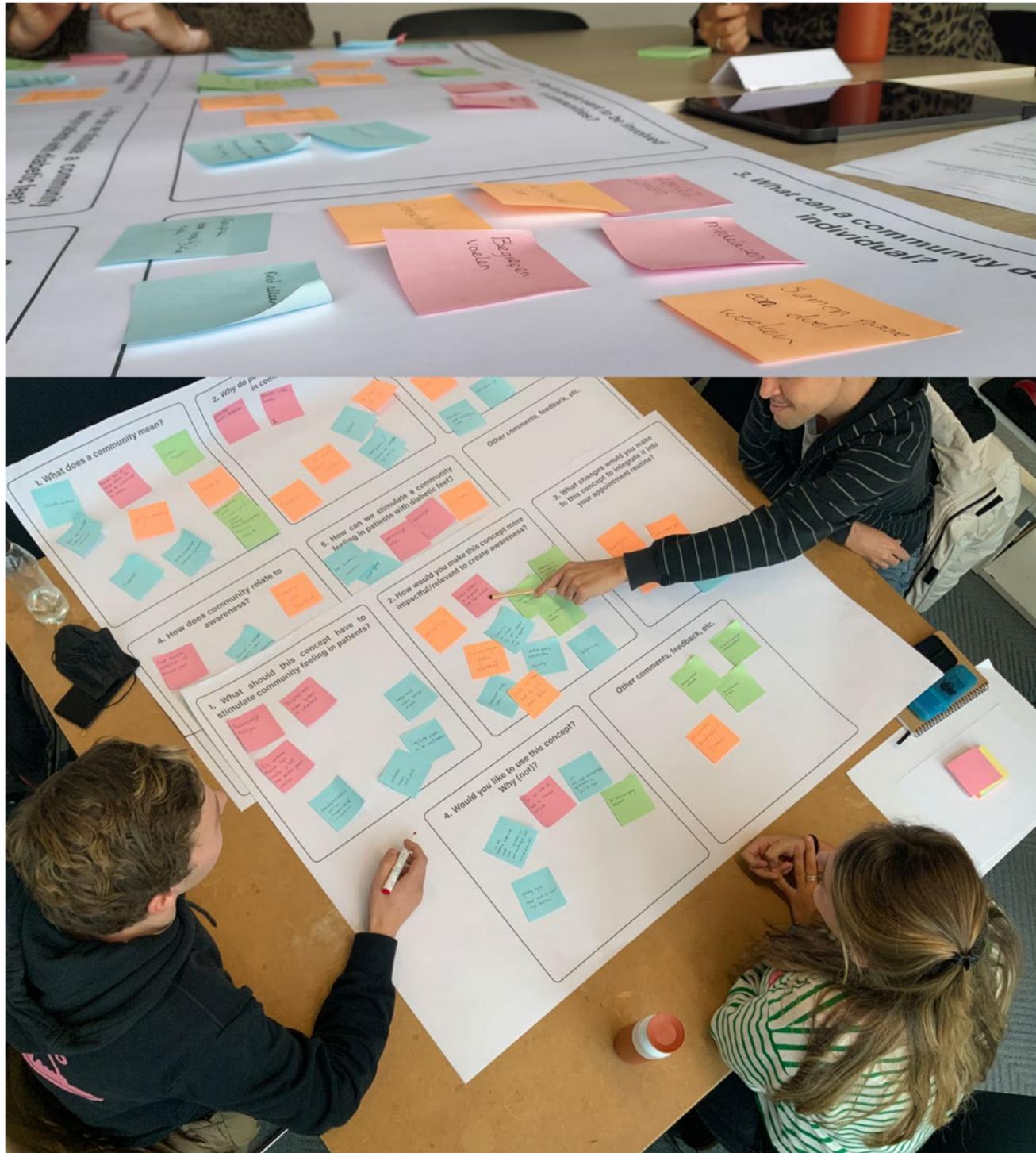

Figure 11: Co-design session

Figure 12: Reflecting on the co-design session

Design decision

As described above, the decision of the final concept was based on three perspectives:
• Experts evaluation;
• Co-design session;
• View of design team.
It was decided to focus on concept 2: the AR Lens, since it showed more possibilities and minor flaws.

Final concept

The final concept was developed on top of the AR Lens concept, improving on aspects mentioned by the experts and the participants of the Co-Design Session. As can be seen in appendix 6, most of the suggestions and feedback were regarding the interface and user experience.
Two aspects that stood out addressed how practical the device must be in order to be effective and how extensive the range of signs and intensity should be so that the podiatrist can easily adapt it to each different patient's condition.

To refine the concept, a few more iterations of sketching and 3D modelling were performed with further discussion of aspects such as ergonomics, aesthetics, durability, and usability until the selection of the final alternative (see figure 13).
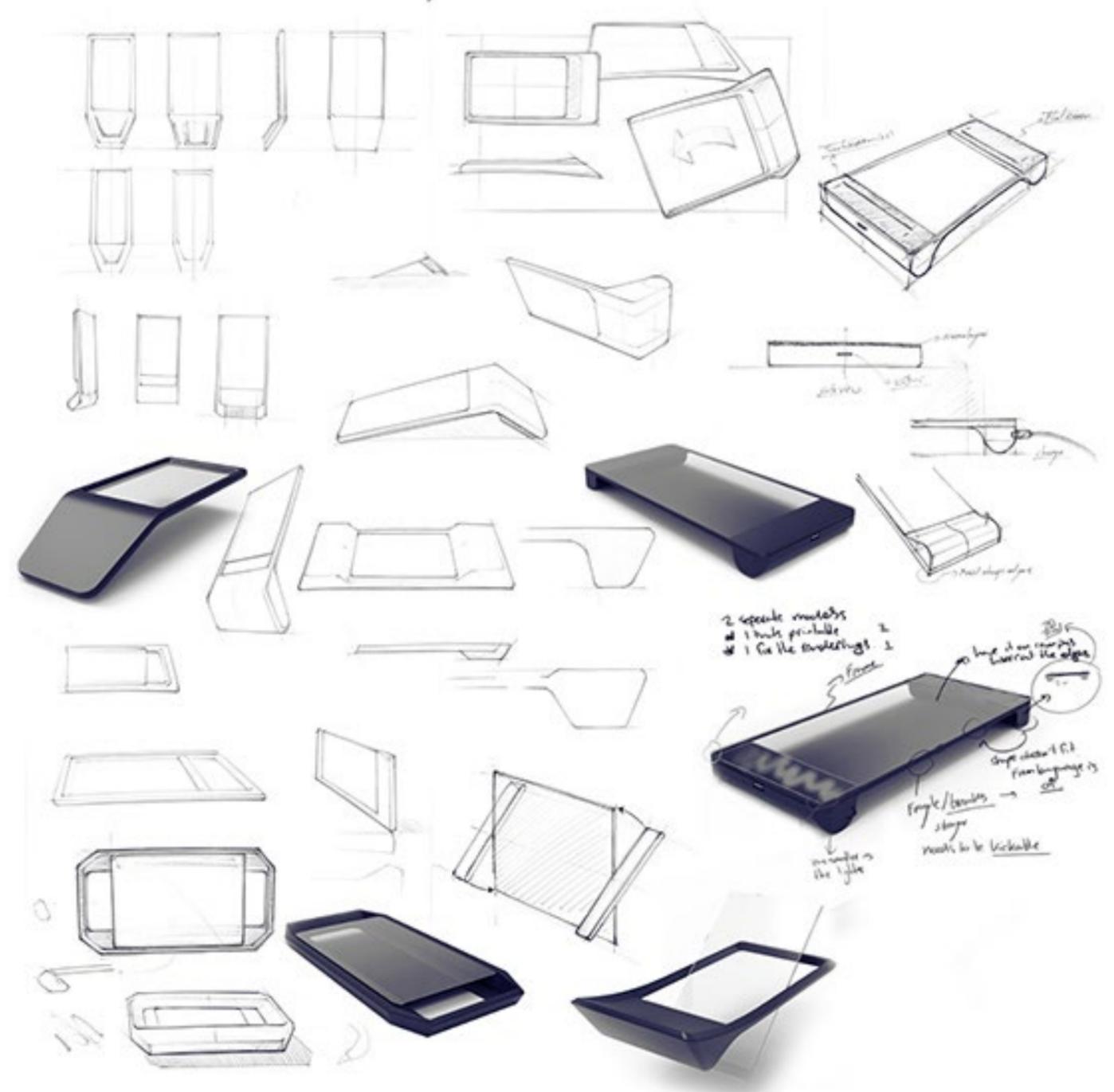

Figure 13: Sketches AR lens concept

Final Concept

VoetZie uses augmented reality technology to show patients how signs of complications might appear on their own feet. The idea is to use a visual and direct approach to explicitly demonstrate the potential risks of not taking care of feet. Therefore it helps to create awareness in patients, not only about their condition but also about the benefits of prevention.

Design is simple and straightforward considering aspects of hygiene and durability. Like medical equipment, it must not look fragile however, presenting a modern look that matches its technology (see figure 14). The main touchscreen, the "lens", is protected by a slim frame that acts as a mobile phone cover. On both sides, ergonomic handles provide a firm grip to allow the device to be held with either hand while the podiatrists can point details to discuss with patients. It can be charged via a USB-C cable (see figure 15).

The interface is also simple and direct in order to keep the device easy to use, as suggested by the participants in the Co-Design session. The right side presents a menu with options of signs of risks such as calluses or ulcers and a button to switch the camera mode to infrared. On the left side, there is a slider that controls the intensity of the signs and a camera button on the bottom (see figure 16).
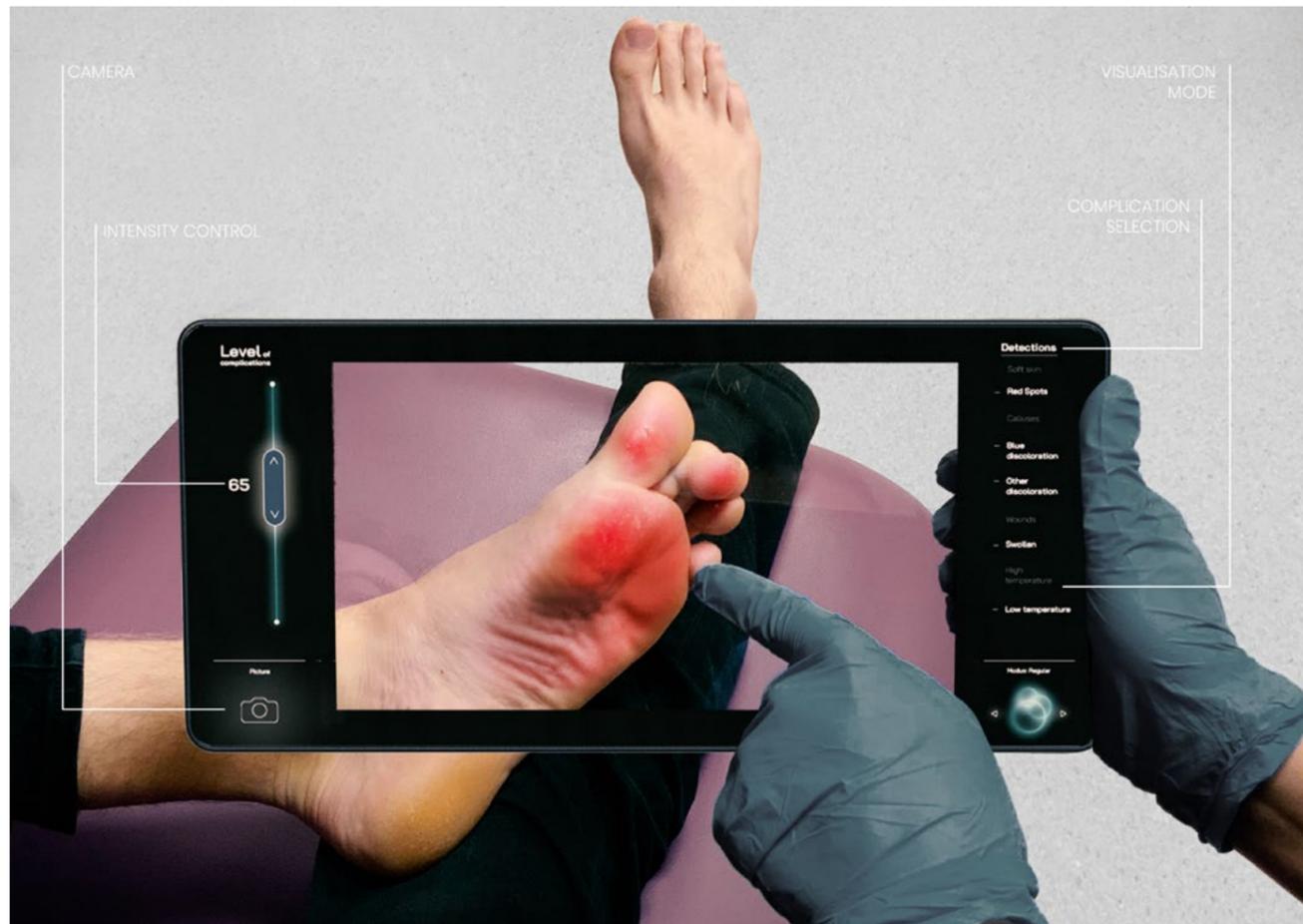

Figure 14: VoeZie

Figure 16: VoeZie - interface functionalities

Figure 15: VoeZie - Aesthetic features

VoetZie's functionalities allow podiatrists to show patients the signs they should look for when scanning their feet. They can choose from different kinds, such as red spots, calluses, or wounds, and use a slider to control how severe they want it to appear (see figure 17). There is also a temperature function that can show the regions of the feet which are warmer and colder than expected which is a warning sign to contact the podiatrist immediately. Finally, VoetZie also allows the podiatrist to take a picture of a patient's feet that can be sent to them via the Diabetes Voetencheck app.
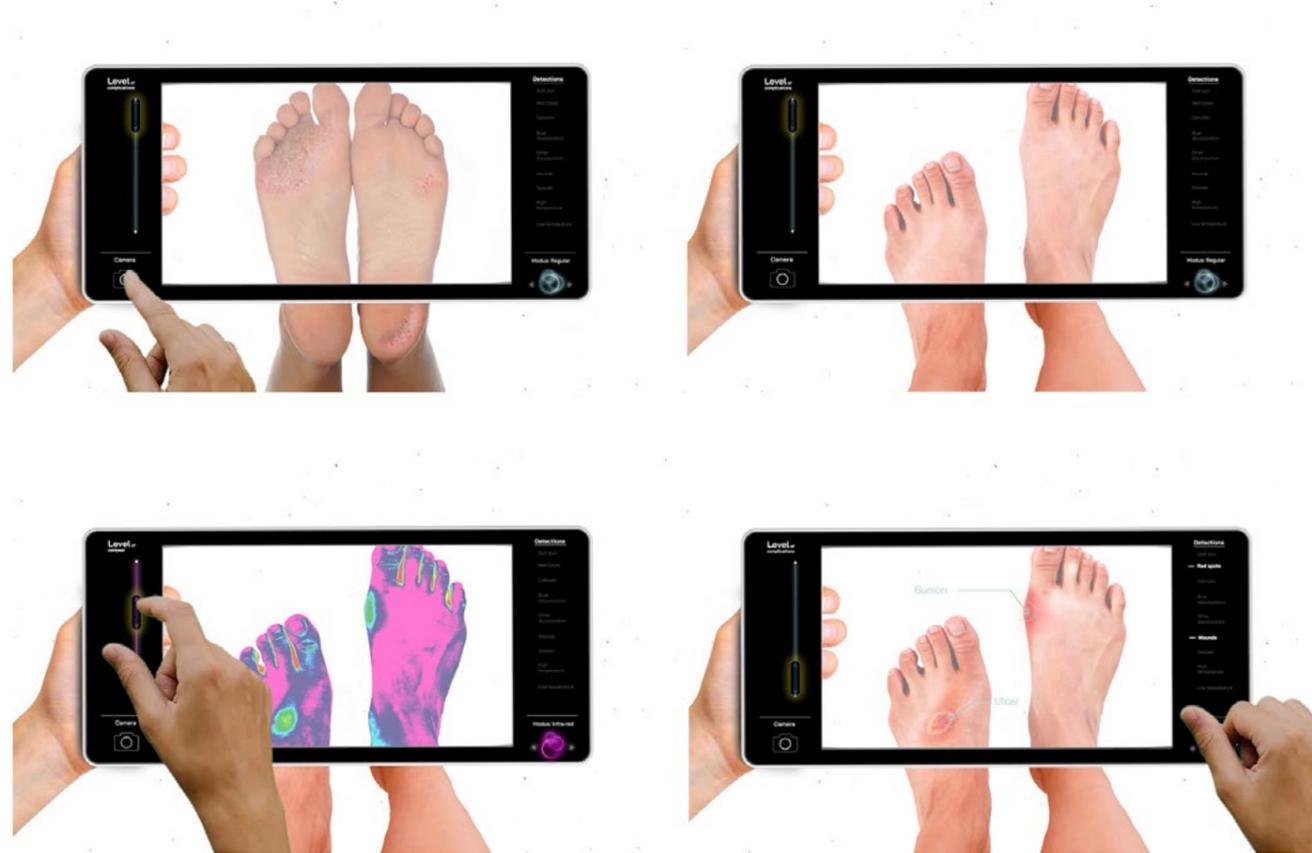

Figure 17: VoetZie - functionalities

Concept video :
https://youtu.be/Ig0Nt8eelns

Technology

Regarding the enormous scope of the topic of augmented reality and the project's timeframe with minimal time left to treat the technical part of the concept, the technical feasibility of VoetZie will be approached from a more top-down perspective, combined with some small scrutinised aspects.

There are multiple developments and technical levels for this concept to be implemented, where some developments are more comprehensive than others. For this reason, a comparison is made between the costs and the functional benefit(s) of these developments. As a result, a concept is chosen that has the right balance between the fundamental functionality of creating direct awareness and the limited budget of RondOm Podotherapeuten. This concept will be discussed in this chapter, the others can be found in the recommendations.

Hardware

VoetZie is a device that contains several parts. The main part is the display, a non-transparent touch-screen, a flat surface that is easy to keep clean and sterile, which is important considering the clinical environment it will be in. The screen has two handles that are designed to have an ergonomic grip and function as housing to store the electronics, which is completely feasible considering the mobile and tablet devices we use these days.
Voetzie will have two front cameras. The first camera is a regular camera that is used to film the feet and the other camera is a thermal image camera that is using thermography. Thermography is a test that uses an infrared camera to detect heat patterns and blood flow in body tissues. There are companies like Infiray that make thermal cameras like this and are not too expensive or too big to fit the housing (InfiRay, n.d.).

Software

Voetzie will contain a processing unit or a computer vision system to interpret the information. The kind of AR that VoetZie uses is Marker-based AR. This type of AR is chosen because it is used when what the user is looking at is known (Katiyar et al., 2015). Thereby, it is proven to be accurate and sufficiently robust, and easy to implement, because so far almost all AR development kits support marker-based tracking methods (Wagner, et al. 2005). The AR application gives the position of the marker in a camera coordinate system that triggers the augmented reality experience (Dash, et al. 2018). When the application recognizes the marker an AR effect will be integrated and overlayed over the real-world environment. This means VoetZie will need to be supported by feet and complications markers that are predefined by the system creator in advance, where podiatrists can use these predefined markers to complete the construction of the specified content.

Final concept evaluation

The final concept evaluation was done to test it with potential users: podiatrists and patients. The goal was to find out whether the VoetZie would create awareness about the risks of diabetic feet during an appointment. Tests were done in three ways to obtain feedback from different perspectives. For each one, a video presenting a physical prototype (see figure 18,19) was used to demonstrate the concept, whereafter questions were asked. An elaborate evaluation of the user test can be found in appendix 7.

Figure 18: physical prototype

Figure 19: physical prototype

1. Quantitative research with patients

32 patients from RondOm Podotherapeuten between the ages of 51 and 90 diagnosed with diabetes with a high risk of developing problems at their feet have participated in this research. Data was analysed by making graphs of the outcomes and can be found in appendix 8.

For most participants, 28 out of 32, VoetZie was understandable and the participants had a positive or very positive first impression. The majority, about 27 participants, think that it would help them to understand what signs they should look for on their own feet and that it would help them to better understand the risks. Besides that, 27 participants think that it would motivate them to check their feet more often.

2. Qualitative research with patients

For this research, one of the researchers went to the podiatry practice to join appointments with patients where the patient was asked questions about VoetZie. Four patients of RondOm Podotherapeuten that were diagnosed with diabetes (and diabetic feet) participated. Results were analysed and a summary, including quotes, was written (appendix 9).

Based on this research, it can be concluded that at first, all patients did not see the advantages of VoetZie for themselves as patients. Most of them mentioned that it might be useful for the podiatrist. However, when the researcher asked about the advantages for themselves, they mentioned that it might also be useful for them. One of the patients mentioned that VoetZie would have been useful for him before he had developed wounds, because VoetZie makes the risks clear and understandable since you can see it immediately on your own feet.

3. Research with podiatrists

This was approached in two different ways: a questionnaire sent to podiatrists and a presentation given for the client (RondOm Podotherapeuten and Team Technology Support for Diabetes) with further discussion about the concept. The reason for that was to seek feedback from more professionals than those present at the meeting with the client. The answers from the questionnaire, data analysis and the notes of the discussion can be found in appendix 10.

The podiatrists describe the concept of VoetZie as innovative, stimulating, useful, complex and time-saving. They are inspired by the approach and concept. Most podiatrists think that VoetZie could have a useful contribution to their appointments with patients because it makes the risks visible and more understandable for patients. However, podiatrists prefer not to have another device to bring with them and the use of VoetZie should not cost extra time during the appointment. They were also concerned about feasibility and they asked about the possibilities of combining it with the current application, to stimulate self-management.

General outcomes

It should be stated that it was not possible to involve the specified target group of patients, because the researchers were dependent on the patients that filled in the questionnaire and visited the podiatry practice. However, most patients were not aware of the risks of diabetic feet.

Overall, it could be concluded that VoetZie could make the patients more aware of the risks and the importance of prevention. However, these outcomes are only based on a video they have seen. Participants have not been able to test the product themselves.

Discussion

As mentioned in this report Voetzie is still in an early conceptual phase of development. Therefore, only the conceptual limitations of the current design and user tests will be addressed in this section.

One of the largest constraints of VoetZie is the limited accessibility of showing the back of the patients' feet. Patients are required to have a certain level of agility to bend their legs in a position the back of the feet can be directly seen by both the podiatrist and patient. Concerning the average patient, this is not an option. VoetZie does have the option to take pictures of the feet including the AR layer, however, this extra step will be in contradiction with the aim of having a direct approach.

During the user tests, a newsletter with the questionnaire was sent to patients of RondOm podotherapeuten. Therefore, it was not possible to only recruit participants within our target group. However, when analysing data it was noticed that this group has been the majority of the user test.

Participants that have not been able to use the product in real life. Instead, a video of VoetZie was presented, making it more difficult for them to empathise with the concept. Some participants mentioned that the video was difficult to understand due to the voice-over of the video being in English, while subtitles were in Dutch (appendix 8, 9 and 10).

Conclusion

This project was commissioned by RondOm Podotherapeuten in collaboration with 'Team Technology Support for Diabetes' of Fontys Hogeschool. The goal is to increase the patients' awareness about the potential risks of not taking proper care of their feet and the benefits of prevention.

An iterative design process was followed to convert research into a final concept. VoetZie was designed by involving experts and patients during different stages of the design process to create insights and receive evaluative feedback consisting of interviews and a co-design session with podiatrists.

VoetZie enables podiatrists to show patients initial warning signs projected on their own feet during an appointment. The concept uses augmented reality technology to provide a better understanding of complications with the aid of a visual and direct approach. Augmented reality fills the gap of the patient's capability to visually imagine these complications.

After doing user tests with patients to evaluate the concept, it can be concluded that it makes patients more aware about the risks of diabetic feet, because it helps to visualise and strengthen the explanation of the podiatrist during an appointment. However, VoetZie is still in its conceptual phase, which means that recommendations have been set up to the continuation of this project.

Future work

User experience

As a starting point, a study to validate the hypothesis that generated the concept is recommended. This research should provide evidence that showing patients the signs they should look for, will raise their awareness about the risks of diabetic feet thus stimulating preventive behaviour.

The concept

The software development part of the design is still very open. Therefore, grounded research and testing on the software feasibility are recommended. The follow-up steps that can be taken into account are designing a working interface that is connected to the Diabetes Voetencheck app and/or a working marker-based AR system. For the AR it is suggested to make use of accessible marker-based applications like Snapchat's ''Lens Studio'' (Snapchat, 2019).

The strength of the concept can be expanded by applying technology that makes the AR content even closer to the real world. Therefore, it is recommended to further discover the different types and developments of AR and the related opportunities, such as using a transparent screen over a non-transparent screen. There are already products on the market that use such technologies, like the HoloLens 2 from Microsoft or Holographic augmented reality display from WayRay (Microsoft, n.d.), (WayRay, n.d.).

An initial question that kept coming back was: "How is the podiatrist able to show the back of the feet?". There are different ways to film the back of the feet. The first option is to integrate a front camera. This works as follows: the podiatrist holds the device under the feet of the patient, the front camera records the feet and displays a more mirror-like image on the screen, comparable to taking selfies. Another option is to integrate a ''smart mirror'', a device that works both as a mirror and an interactive display (Pesala, et al. 2021).

Application

The connection between VoetZie and the Diabetes Voetencheck App is not yet defined. Therefore, it is recommended to design a connective module that connects VoetZie to the functionalities of the Diabetes Voetencheck app to let patients re-experience the appointment at home to stimulate self-management.

The prototype

The final recommendation is to make an actual working prototype and to test this in both lab conditions and in context, during podiatrists' appointments with patients.

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