Blood sugar measuring and its challenges for visually impaired people

Qualitative descriptive study

Master Thesis

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Declaration

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Preface

In these two years of my Master programme in Digital Healthcare I gained a lot of valuable knowledge and experience for my further life. This is why I want to thank my university FH St.Pölten for making this education available for me and all my colleagues and lecturers for supporting me throughout those two years and probably even further on.

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Finally, I want to thank my family, friends and my love Wolfgang for accompanying, supporting, encouraging and motivating me. Without them I would not have made it this far!

Thank you

Abstract

This thesis discloses the problems and challenges that visually impaired people have to master while measuring their blood glucose levels. Most medical devices present their data only visually. To see how visually impaired people deal with their blood glucose meters and if they are accessible to them, six visually impaired people volunteered to be interviewed on that matter. To get to know which user interface requirements visually impaired people have when measuring their blood glucose levels and how their devices correspond to those requirements they got asked about their health background, their blood glucose meters and their accessibility, as well as the menu navigation and what features they would like to see in the future. Additionally, an expert interview has been held to get another perspective on that topic. The interview results and new technologies of non visual data presentation are discussed.

Keywords: visual impairment, diabetes mellitus, blood glucose meters, data presentaion

Kurzfassung

Diese Arbeit behandelt die Problematik und Herausforderungen beim Blutzuckermessen mit Sehbehinderung. Die meisten Medizinprodukte präsentieren ihre Daten nur visuell. Um zu sehen, wie sehbehinderte Personen mit ihren Blutzuckermessgeräten umgehen und ob diese barrierefrei sind, wurden sechs Freiwillige zu diesem Thema interviewt. Zur Erfragung welche User-Interface Anforderungen sehbehinderte Personen bei der Messung ihres Blutzuckerspiegels haben und wie ihre Geräte diesen Anforderungen entsprechen, wurden sie zu folgenden Themen interviewt: ihren Gesundheitszustand, ihren Blutzuckermessgeräten und deren Barrierefreiheit, sowie der Menüführung und Funktionen, die sie zukünftig gerne sehen würden. Zusätzlich wurde ein ExpertInneninterview durchgeführt, um dieses Thema von einer anderen Perspektive zu beleuchten. Die Interviewergebnisse und neue Technologien der nicht-visuellen Datenpräsentation werden diskutiert.

Schlüsselwörter: Sehbehinderung, Diabetes Mellitus, Blutzuckermessgeräte, Datenpräsentation

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1 Introduction

The human eye is one of our most important organs. Every second more than 10^{10} bits of images reach our retina and about $3x10^6$ bits are processed for the optic nerve, but we are aware of just less than 10^4 bits per second (Anderson, Van Essen, & Olshausen, 2004, p. 3). Still, compared to other senses, most information is perceived visually. When this ability of visual perception is gone, a lot of information is lost as well and has to be compensated by other senses. For blind or visually impaired people their hearing becomes very important and their sense of touch allows them to read through their fingers. This thesis deals with the problems of visually impaired people with receiving data information that is usually distributed visually using example of blood glucose meters. Not only with blood sugar measurements, but health related measurements in general, the data is often displayed as numbers or curves for patients and healthcare professionals to read. But since there were 318.000 people in Austria (3,9% of population) with permanent reduction in their vision in 2007 (Leitner, 2008, p. 1133) and about 380.000 severely disabled people due to their vision loss in Germany in 2015 (Statistisches Bundesamt, 2016, p. 1), there should be more solutions for data display than just reading/seeing it.

To find out in which areas there is still catching up to do regarding blood glucose meters and what requirements would be needed for visually impaired people, three research questions have been formed:

1. What interface requirements do visually impaired people have, when measuring their blood sugar levels?
2. How are the blood glucose meters corresponding to those requirements?
3. Where are the difficulties of common data distribution for visually impaired people?

Six visually impaired volunteers with diabetes, three from Austria and three from Germany, have been interviewed on the topics of state of health, usability/handling and future visions. They were contacted via social media groups, institutions for blind and visually impaired people and personal contacts. The interviews were held in person or via telephone, included 23 German language questions and took about 15 Minutes each. Ways of non-visual data distribution have been researched, analysed, compared and also checked to see if they meet the requirements of visually impaired people. All interviews were recorded, transcribed in standard German and explicated objectively. Furthermore, the results were discussed and compared with current research. Also, one expert interview has been held with a product manager from a diabetes department of a global healthcare company.

This thesis also includes a theoretical background to diabetes mellitus, the causes of visual impairment and different kinds of data presentation. The conclusion covers the author's personal opinion, as well as an overall summary of this thesis.

2 Theoretical Background

This chapter gives an overview of the theoretical background regarding this master's thesis. The main topics are diabetes mellitus and how it is measured, the causes of visual impairment and different kinds of data presentation.

2.1 Diabetes Mellitus

Diabetes mellitus is a metabolic dysfunction which causes a high level of blood sugar. We differentiate between two main types and various subtypes.

2.1.1 Diabetes Types

Type 1 diabetes mostly occurs in younger people and is characterized by the destruction of islet cells, which are necessary for the production of insulin. This destruction is triggered by an autoimmune reaction that has its roots in the patient's genetics, as well as a viral infection. (Schmeisl, 2015, p. 4)

The most common symptoms that raise suspicion of diabetes mellitus are polydipsia, which is intense thirst, and polyuria (increased urination), with accompanied nocturia (waking up at night because of the urge to urinate). Also, patients are tired and experience weight loss. Occasionally, type 1 diabetes also occurs in older people. In that case it is called "late autoimmune diabetes of the adult", short LADA. Because of the increasing number of overweight people it is getting harder to differentiate LADA from type 2 diabetes, since the symptoms are quite similar. (Levy, 2016, p. 25)

While patients with type 1 diabetes produce not enough insulin, type 2 diabetes patients produce enough insulin at first, but develop a resistance. Due to that resistance more insulin is produced which in the long term damages the pancreas and its islet cells. The main cause of this insulin resistance is the patient's body weight and lack of movement. The energy is stored into fat which produces hormones that lead to the destruction of islet cells. Type 2 diabetes also is a consequence of the metabolic syndrome, a combination of high blood pressure, metabolic dysfunction, high level of visceral fat (abdominal fat) and high fasting blood sugar. (Schmeisl, 2015, p. 6)

Gestational diabetes is diagnosed during pregnancy, regardless of if there had been increased blood sugar levels before pregnancy that hadn't been detected beforehand. The first occurrence of high blood sugar levels during pregnancy, as well as diabetes that would have manifested at the same time even without pregnancy are also categorized as gestational diabetes. Women with higher weight and/or older women are more susceptible of getting gestational diabetes. There is a greater probability of developing metabolic syndrome and diabetes for children in younger years, if the gestational diabetes of the mother is diagnosed too late. (Schmeisl, 2015, p. 218)

Pancreatic diabetes can be caused by various diseases of the pancreas, including trauma, cancer and infections, as well as total removal of the pancreas. Every dysfunction of the pancreas causes an insufficient insulin production and can lead to diabetes mellitus. (DeFronzo, Ferrannini, Zimmet, & Alberti, 2015, p. 8)

2.1.2 Diabetes Therapy

To decide on the right therapy it is important to know the exact type and cause of diabetes.

With type 1 diabetes it is necessary to get the right amount of insulin to keep the normal level of blood sugar between 80 and 120 mg/dl. The conventional insulin therapy recommends an insulin mix dose twice a day. Since the patients can not control the amount of insulin any further, they have to stick to a strict diet to keep their blood sugar levels within a normal range. Because of the inflexibility of this therapy the most recommended therapy for patients with type 1 diabetes is the intensified conventional insulin therapy. The amount of insulin is calculated by the patients depending on their meals, activity and basal insulin level. That way they can choose the size of their meals or even skip them and are more flexible in their daily lives. The drawback with this therapy is that the patients have to inject the insulin at least 3-4 times a day and check their blood sugar levels regularly. (Schmeisl, 2015, p. 77)

If type 2 diabetes is caused by metabolic syndrome, the main goal is to lose weight. So, the therapy of choice would be exercise and a healthy diet. The weight reduction is usually accompanied by an improvement of blood glucose levels, as well as blood pressure and blood lipids. (Schmeisl, 2015, p. 8f.) If weight loss alone is not enough, or if the diabetes is caused by insulin resistance rather than too much visceral fat, medication has to be used. One of the most common medications is "metformin", a biguanide that lowers the production of glucose in the liver and improves the absorption of blood sugar into muscles and fat. The pills can only be taken, if the patients have no problems with their liver, kidneys or heavy cardiovascular diseases. Also, 20% of the patients taking metformin are having gastrointestinal complaints. Metformin can be combined with other substances like DPP-4-inhibitors, SGLT-2-inhibitors and thiazolidinediones. Another medication for type 2 diabetes is an incretin mimetic, a GLP-1-antagonist. That means it resembles the hormone incretin, which is located in the mucous membrane of the small intestine. This hormone regulates the amount of insulin that is produced in the pancreas. Incretin mimetics are injected under the skin and are applicable to patients with moderate renal insufficiency. (Schmeisl, 2015, p. 33ff.) As with type 1 diabetes, type 2 diabetes can be treated with insulin as well. The therapy and which kind of insulin will be used, are linked to the cause of the high blood sugar levels. The basal supported oral therapy combines oral medication with basal insulin that is injected in the evening. This prevents high fasting blood sugar levels. The supplementary insulin therapy works best with short acting insulin, but humane insulin can be used as well. Since humane insulin acts longer, it can lead to hypoglycemia. This therapy works very well with patients that still have some functioning islet cells that need to be supported with insulin injections while/after meals. (Schmeisl, 2015, p. 68ff.) The insulin can be injected with a syringe or a pen by the patients themselves or via insulin pump.

2.1.3 Blood Sugar Measuring

There are many ways to measure the glucose level in the blood. The most common one is via blood glucose meters. A test strip is inserted into the device and then a drop of blood has to be placed on the strip. After a few seconds the blood sugar level is shown on a display. But, blood glucose meters as we know them today were invented only about 45 years ago (Clarke & Foster, 2012, p. 83). There were various approaches on detecting sugar in the patient’s urine back in 1841, 1848 and 1850 when Trommer, Von Fehling and Maumene let the urine react with different substances, nevertheless, it was Stanley Benedict who developed a copper reagent which was used for the following 50 years (Clarke & Foster, 2012, p. 84). Starting from 1970 the first blood glucose meters were produced, the first one with a display debuted in 1980 and with every new generation of device, the measurements got more precise (Clarke & Foster, 2012, p. 86). Nowadays the measurement can be done with a number of methods, depending on the device.

One of these methods uses optical sensors that read the absorption of light going through the blood after it has reacted with a chemical on the test strip. Another method measures the electric current that results from a chemical reaction of an enzyme from the test strip with the glucose from the blood. (Wascher & Pongratz, 2015, p. 37) (See Figure 1)

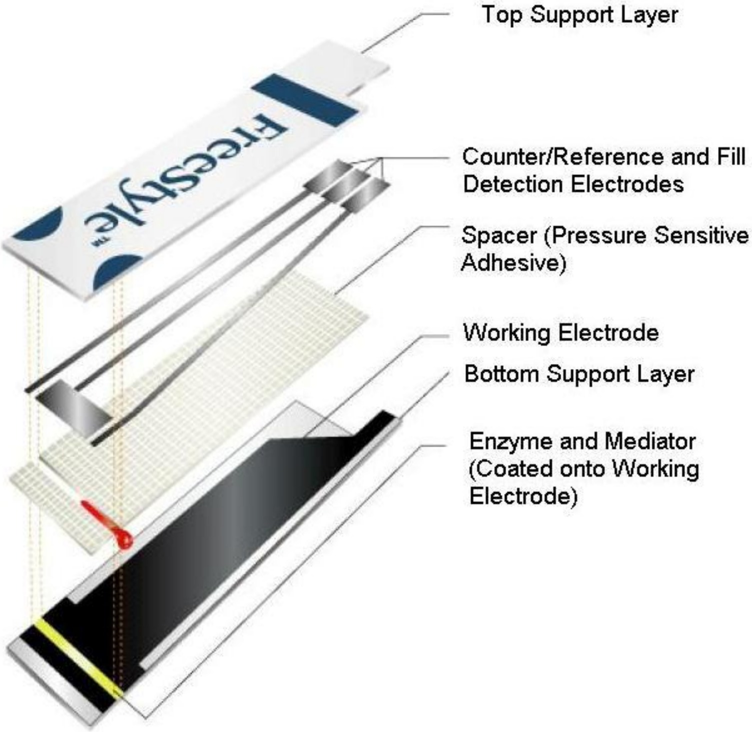

Figure 1 [Freestyle test strip] (2018). Retrieved from http://www.solaramedicalsupplies.com/freestyle-test-strips-100ct

Monitoring sensors are becoming more popular since the patients are not forced to prick themselves several times a day. Almost painlessly the sensors are attached 5-8mm into the tissue at the back of the upper arm. Depending on the device, they can be worn up to two weeks, even while showering and during sports. The blood glucose level is measured every few seconds and saved every 1-5 Minutes. Via reading device or smart phone application the measurements can be read and some devices even show trends and diagrams of the last eight hours.

The blood glucose level can also be measured at the laboratory. This method uses the blood plasma and is very exact. (Wascher & Pongratz, 2015, p. 37)

Another way to measure the blood sugar is by the amount of ketones, like acetone, in the urine. Test strips are held into the urine and through chemical reactions the colour of the strips changes. The strips are then compared to a colour palette which translates colour to glucose. This test is not as accurate as the blood tests but easy to use. Nevertheless, a positive test can also be an indicator for renal diseases or weight loss, since acetone is produced when the body burns fat instead of carbohydrates. (Schmeisl, 2015, p. 28)

2.2 Visual Impairment

The majority of stimuli from our environment are perceived visually. That is why many people think of their eyes as their most important sense organ and blindness as the worst disability.

2.2.1 Congenital Diseases

There are different origins of congenital diseases, some have a genetic disposure and others occur during pregnancy, be it because of infections, trauma or genetic mutations. Also, the appearance of the diseases can be very different, they can be diagnosed soon after birth or develop years later.

Congenital cataracts can be caused by rubella, mumps, hepatitis and toxoplasmosis infections in the first trimester of pregnancy. Furthermore, congenital cataract can be inherited autosomal dominant, autosomal recessive, spontaneous or X-chromosomal. The lens of the newborn appears cloudy and has to be removed in order to prevent blindness. (Lang, 2008, p. 174f.) Congenital toxoplasmosis can also cause a retinal scar on the macula, which is the area with the highest resolution and where colour is perceived. Children with such a scar often have severe vision loss. (Lang, 2008, p. 354)

Retinitis pigmentosa is a retinal disease. Its characteristics are a progressive dystrophy of the retinal rods, night blindness and consequently vision field defects. There are many different forms of retinitis pigmentosa, e.g. the reversed retinitis pigmentosa with a cone-rod dystrophy, but the rod-cone dystrophy is the most common one. The appearance of the first symptoms depends on the genetic origin of the disease and can occur from early age until middle age. The first symptoms are sensitivity to light and night blindness. Later, the patient experiences vision reduction, vision field defects (typically from the periphery progressing to the centre) and reduction of colour perception. (Lang, 2008, p. 347 f.) 15 – 20% of retinitis pigmentosa patients also suffer from usher-syndrome. Additionally, to the rod-cone dystrophy, usher-syndrome patients are diagnosed with hearing loss. We differentiate between three categories depending on the patient’s age when the first symptoms start to appear. (Kaiser & Flammer, 1999, p. 73)

Another reason for vision impairment is congenital nystagmus. Without being able to stop, the eyes constantly move in jerky or pendulum motions. Frequency and amplitude can change with the direction of view, often a deceleration of the nystagmus can be found when the eyes are converged. Because of those movements the patients can not focus clearly and have a reduced vision. (Lang, 2008, p. 496) Albinism can appear just in the eye (ocular albinism) or combined with skin and hair (ocular cutan albinism). It is caused by a metabolic disorder that leads to hypopigmentation, which is the lack of melanin. The iris is light blue and the retinal pigment epithelium is lacking pigments which leads to severe light sensitivity. This sensitivity and the additional nystagmus, which is often paired with albinism, leads to vision reduction. (Lang, 2008, p. 198f.)

An undiagnosed and untreated congenital glaucoma inevitably causes damage to the optic nerve which ends with severe vision field defects and vision loss. To prevent this, children with unusually big eyes and cloudy cornea, as well as children that are especially light sensitive and have teary eyes should undergo eye pressure measuring. If the eye pressure is too high (normal range is 10 – 20 mm/hg), surgery is the only solution. (Lang, 2008, p. 267 ff.) Congenital glaucoma can also appear together with neurofibromatosis. Typical for type 1 are six or more café-au-lait spots, two or more neurofibromas, lisch-nodulas, learning difficulties in 40-60% of the patients with neurofibromatosis and optic glioma in 15%. Type 2 shares some of the symptoms of type 1, except for the optic glioma and lisch-nodulas. It appears far less often than type 1. Nevertheless, with neurofibromatosis type 2 the chance to be diagnosed with some kinds of tumours like meningioma and schwannoma is higher. Patients can also suffer from cataracts, as well as other neurological symptoms due to the various tumours. (Kaiser & Flammer, 1999, p. 87 ff.)

Depending on the location, tumours can lead to many different appearances of visual impairments. Most common are vision field defects, vision reduction and colour sensitivity disorders. If the tumour is located in the eye or between eye and chiasma, the defects will appear on the affected side. Is the tumour located after the chiasma, the defects can be seen on both eyes. Tumours with strong malignancy have to undergo surgery, combined with chemotherapy and radiation therapy. If an infiltration of the chiasma is expected, the whole optic nerve might be removed, sometimes even the whole eye has to be enucleated. (Schiefer, Wilhelm, Zrenner, & Burk, 2003, p. 163 ff.)

Retinopathy of prematurity is only found in children that are born premature. The retinal blood vessels start growing from the optical nerve and spread across the retina. This process happens mainly during pregnancy, but the temporal vascularization finishes a few months after the child is born. If the child is born prematurely, the blood vessels are not as developed as they would be with a child that is born at full term. The underdeveloped vessels can not supply the whole retina, so some parts might get ischemic. This ischemic retina leads to the production of VEGF, a growing factor. Because of the VEGF, the blood vessels start growing rapidly which causes tractions, bleeding and, at worst stage, retinal detachment. (Root, 2009, p. 103) Premature children usually get additional oxygen, as their lungs might not be fully developed. The amount of oxygen is far more than the children received intra uterine and can weaken the newly formed blood vessels, which leads to more bleeding. The ischemic retina is treated with cryotherapy, retinal laser or anti-VEGF injections like Avastin and Lucentis. Depending on the prematurity and weight of the child, as well as the stage of the disease, the children can have normal vision to severe visual impairments.

2.2.2 Acquired Diseases

Vision loss can occur at any time throughout the life. But with age, the risk of getting eye diseases, that lead to visual impairments, rises.

Glaucoma is one of the most dangerous eye diseases since the vision loss is slowly progressing and the patients do not feel any pain. There are many forms of glaucoma, but the chronic open angle glaucoma is the most common one. It is caused by a reduced drainage of the trabecular meshwork where the aqueous flows into the canal of schlemm. This lack of drainage leads to high intra ocular pressure which damages the optic nerve. Another cause of high intra ocular pressure is a closed angle glaucoma, also known as acute glaucoma. In this case the drainage is totally blocked because of the shallow angle between iris and cornea. The closed angle glaucoma is very painful and has to be checked as soon as possible to prevent acute vision loss. Glaucoma can also be a side effect of other diseases like neovascularization of the iris, pigment dispersion syndrome and pseudoexfoliation syndrome. (Root, 2009, p. 34 ff.) The most important examination to diagnose glaucoma is to regularly measure the eye pressure. This can happen with a non-contact tonometer, eye care tonometer or Goldmann applanation tonometer, the last one is the most accurate method. Furthermore, the vision and the vision field have to be checked on a regular basis. An examination of the fundus is also necessary to identify possible damage to the optic disc due to the high intra ocular pressure. A nerve fiber analyzer can detect damages to the optic nerve at an early stage as well. The most common therapy for glaucoma are beta blocker eye drops which the patients have to use daily. In case of a shallow anterior chamber angle a laser iridotomy can be done to accomplish a better flow of the aqueous. When the medical therapy is not working, trabeculectomy is used. At the trabeculectomy an artificial canal is created that helps with the drainage of the aqueous. Another method is the laser trabeculectomy where a laser is shot into the trabecular meshwork for better drainage.

Another high-risk eye disease is the diabetic retinopathy. (See Figure 2) Sooner or later almost every diabetic will get diabetic retinopathy. 10 years after the diabetes has been diagnosed more than 50% of the patients suffer from diabetic retinopathy, the number rises up to 90% after 15 years of diabetes. The first symptoms can be seen on the retina. During fundus examination, dot-blot hemorrages can be spotted. This occurs because of the vessel damage due to high blood sugar levels. This form of diabetic retinopathy is called nonproliferative diabetic retinopathy and is more common than the second form, the proliferative diabetic retinopathy. Nevertheless, the second form is much more dangerous since, left untreated, patients can go blind within five years due to the same mechanisms that lead to neovascularization as described earlier with retinopathy of prematurity. (Root, 2009, p. 48 ff.) So far, diabetic retinopathy can only be treated with laser treatment or, in case of vitreous bleeding or traction, the vitreous has to be removed. But, the disease can be prevented or delayed if the blood sugar levels are controlled and the HbA1c is kept low. (Lang, 2008, p. 314 ff.)

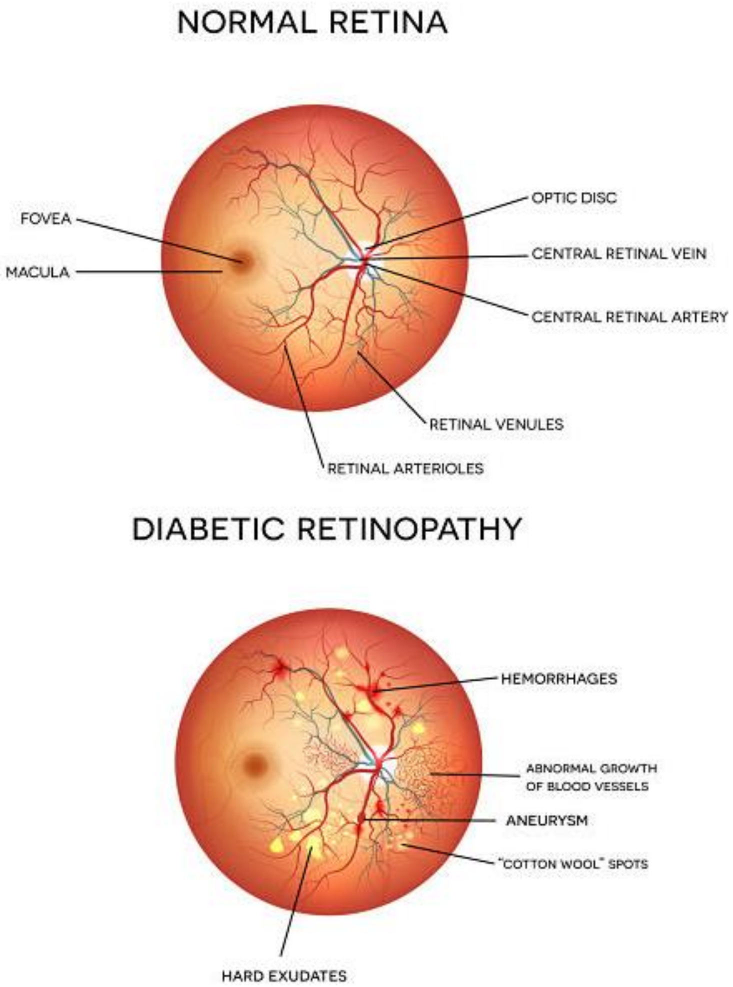

Figure 2 [Normal and diabetic retina] (2018). Retrieved from https://www.southwesteye.com/eye-services-el-paso/diabetic-retinopathy/

With age the risk of getting age-related macular degeneration increases. For patients that are 65-years or older, it is one of the most common causes of blindness. Aside from the age, there are more factors that increase the risk of getting this disease e.g. solar radiation, genetic predisposure and nicotine. (Lang, 2008, p. 337) When the retinal pigment epithelium starts to degenerate, drusen (extracellular breakdown deposits) are formed. Those drusen block off nutrition to the retina which leads to neovascularization. The new blood vessels are very unstable and tend to leak blood, lipids and fluids. Once this stadium is reached, it is called wet age-related macular degeneration. (Root, 2009, p. 57 f.) Drusen can be examined during a retinal exam or with optical coherence tomography. In the dry stadium patients may experience metamorphopsia and reading difficulties due to central vision loss, depending on the location of drusen and retinal scars. Until recently there was no treatment for dry age-related macular degeneration, but it can be stopped with 2RT laser treatment now. This treatment encourages the retina to get rid of the drusen to prevent the progression of the disease. In the wet stadium patients usually suffer from medium to strong central vision loss. This stadium is usually treated with anti-VEGF injections to stop the neovascularization.

2.3 Data Presentation

When data is presented, one often thinks of data visualization. This can be in form of text, numbers, charts, diagrams, pictures, videos and so on. The main key to data visualization is the visual impact. But there are more ways to present data also in a non-visual way, as this chapter will explain.

2.3.1 History of Visualization

People throughout history have always wanted to communicate and share information. Some of the oldest pictures that show us information and could be categorized as visualizations are cave and stone paintings made in the stone age. Later, ways were found to preserve speech with writing and paper. But still, the information was bound to one piece of document and had to be copied manually, if people wanted to share their information. The invention of printing started to rapidly speed up the process of sharing and duplicating data and information:

When Gutenberg invented the movable type he paved the way for mass printing. Due to the individually changeable components of the machine different layouts, paper sizes and letters/signs could be printed in a standardized form. This made books affordable even for the middle class and led to standard principles of layout designs.(Hoober & Berkman, 2011, p. 7 f.)

Technologies developed further and when the computer and the internet became accessible for ordinary citizens the importance of visualization boomed. Graphics, texts and pictures were able to change colour and move. Big amounts of data could be transformed into diagrams, charts or any other form of graphic to make them understandable and more convenient.

2.3.2 Types of Data Presentation

Visualization describes any method to transform and present data in a visual way. Visual stimuli reach our brain very fast and pictures, shapes, colours and signs we already got to know throughout our lives are processed even faster than texts or language. There are two categories of visualization, the process-oriented and the goal-oriented visualization. The first category deals with the process of transforming non visual data into something visual presentable. The second category considers the visualized outcome, which should be simple and understandable for the recipient. (Bassler, 2010, p. 32)

Audio visualization is a subgroup that focuses on the presentation of audio data. Every tune from low basses to high pitches becomes visible and allows us to see music, conversations and other sounds. (Späth, 2017, p. XV)

Haptic visualization becomes more and more important, not just for visually impaired people. It is a term that describes the presentation of haptic information. A lot of haptic information is linked with visual information in the brain and intensifies and reinforces each other for a better understanding. Haptic visualization is often used in medical education e.g. training for operations. Haptic information can be found in everyday objects like mobile phones and gaming joysticks that vibrate in certain situations, but most people are not aware of that information. O'Sullivan and Chang attribute this to the lack of language to describe haptic sensations and complex objects. (McGookin & Brewster, 2006, p. 147)

Acoustic information is useful for everyone. When crossing a street, we do not just look if a car is approaching, but also listen for the noises a car is making. When calling or visiting some else, we depend on the ringing of the phone or the bell and when having a conversation or sitting in class listening to a teacher acoustics are the most efficient way to gain information. Acoustic information is even more important for blind or visually impaired people since it is often the only way to know what is happening around them.

2.3.3 Data presentation and diabetes mellitus

Because of the importance of medical data, it should be presented simple and easy to understand. Many parameters are presented with numbers or in text, however, too much of that can easily lead to confusion, which can lead to mistakes. To keep the information short but still effective, data visualization is used. Numbers can be transformed into diagrams and curves and texts can be summarized with tables. With diabetes mellitus, the most important parameters are the blood sugar levels and the long term sugar level, short HbA1c, both are mostly presented as numbers. Some blood glucose meters also show the previous measurements as a curve to provide a better overview for the user. (See Figure 3)

Figure 3 [Freestyle Libre sensor and reading device showing the measurements of the last eight hours with a curve] (2018). Retrived from https://www.freestyle-diabetes.at/produkte/freestyle-libre/

Another way to let the user know if their measurement is higher or lower than the previous one is a trend arrow. If the arrow is pointing upwards, the blood sugar is increasing and if it is pointing downwards, the blood sugar is decreasing. (See Figure 4)

Figure 4 [MyStar Extra blood glucose meter with a trend arrow indicating a decreasing blood sugar level] (2017). Retrieved from https://www.mystarsanofi.com/products/extra

Furthermore, some blood glucose meters present their data with an additional colour palette. This way the user knows with one look if the measurement is within the normal range, too high or too low. (See Figure 5)

Figure 5 [The OneTouch Verio Flex shows an arrow pointing to a colour depending on the measurement. Green is the ideal range, blue indicates that the blood sugar level is too low and red indicates that the level is too high.](2018). Retrieved from https://www.onetouch.de/produkte/blutzuckermessgeraete/onetouch-verio-flex

Mobile applications for diabetes care and management are getting more popular and often combine those visualisations mentioned above. According to a study in 2014, Arnhold et al. found 656 different diabetes applications for iOS and/or Android that are available in German or English. Since 2008 the appearance of diabetes applications drastically increased: in 2008 6 applications were released and by 2012 267 were released. The applications were categorized and rated by experts for better comparison. The most common functions were for documentation (which also included data analysis and presentation), data forwarding (to share the data with doctors or family) and information purposes. Out of those 656 applications 66 were evaluated in terms of usability. On a 5 point Likert scale, most applications were rated between 3,0 and 4,0. Regarding the accessibility, 86,2% of the evaluated Android applications and 67,9% of the iOS applications had a voice output function. Inverted colour and larger type functions could also be found in some applications, but appeared to show miner improvements. Overall, the accessibility of the applications was stated as very important, especially with users aged over 50. (Arnhold, Quade, & Kirch, 2014)

For visually impaired and blind people the only way to get to know about their measurements so far is via audio output. The measurements are spoken by the device or presented with a peeping sound according to the digits in ones, tens and hundreds. That is why it is important to implement those features into mobile applications and measuring devices and making them accessible.

3 Methodology

For this thesis six visually impaired people and one expert have volunteered to be interviewed. In the following sections the methodology behind these interviews will be presented and explained.

3.1 Target Group

Inclusion criteria for the target group were visually impaired people that are at least 18-years old. Furthermore, they should not be able to read the display of their blood glucose meters from a normal reading distance (30-40cm) without help of a magnifying glass or reading device. Also, they had to be familiar with measuring their blood sugar levels on a regular basis and own a blood glucose meter of any kind.

Exclusion criteria are deaf, mute or deaf-mute people, as well as people who can not follow or understand the interview because of their cognitive capabilities.

For the recruiting, three institutions for visually impaired people, two social media groups for visually impaired people and two social media groups for diabetics have been contacted. One of the institutions sent e-mails to about 400 of their members, informing them about this thesis. Out of these 400 members two volunteers agreed to participate in the interview. Initially nobody was found by the social media groups, when the criteria explicitly asked for people from Austria. A second attempt was then made, in which people from Germany were also asked and three people volunteered for interviews. One more volunteer has been found via personal contacts.

3.2 Questionary

The questionary contains 23 German questions regarding the topics health background, blood glucose meters and data presentation, as well as future visions. The German language has been chosen to offer better understanding for the volunteers. For some questions the ISONORM 9241/10 questionary (Prümper & Anft, 1993) has been used as a guideline. The original questionary contains 42 questions in German that can mostly be answered with a 7-part Likert scale. The statement “Bietet auf Verlangen situationsspezifische Erklärungen, die konkret weiterhelfen.“ has been changed to the question „Bietet ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?“. The statement „Ermöglicht einen leichten Wechsel zwischen einzelnen Menüs oder Masken.“ has been changed to „Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)“. „Lässt einen nicht im Unklaren darüber, ob eine Eingabe erfolgreich war oder nicht.“ has been changed to „Wodurch erfahren Sie, ob die von ihnen getätigte Eingabe erfolgt ist?“ and „Informiert sofort über fehlerhafte Eingaben.“ to „Kommen Fehlermeldungen vor? Wenn ja, wie oft?“.

The remaining questions are designed to create an open interview atmosphere and to avoid the impression of an interrogation. Most of the questions are open questions to invite the volunteers to talk freely. The health related questions ask about their vision loss and how much vision is left, as well as their diabetes type and their latest HbA1c. The health block also includes a question about how often they measure their blood sugar levels per day. The next block of questions deals with the volunteers' blood glucose meters and their accessibility. There are questions about their currents devices, how they got to know about them and about the devices they used to use in the past.

Furthermore, two out of three scaled questions have a scale from one to five and ask about the satisfaction with the current device and the assessment of the menu navigation. In the first case, the number one means not satisfied and the number five means very satisfied. In the second case, one means very difficult and two means very easy. The third scaled question asks for the best, the second best and the least important feature of their blood glucose meter. Some questions aim to seek out the accessibility of the blood glucose meters by asking how their devices are corresponding to their visual impairment and how they know if their actions has been entered when navigation through the menu, as well as the handling of the device. Moreover, a hypothetical question about the perfect blood glucose meter has been chosen to leave room for creativity and to respond to the wishes of the volunteers. For a more detailed look at the questions, the original questionary, used for this thesis, is attached to this thesis. (see Appendix, Interview Questionary)

“Das Szenario erlaubt einen spielerischen Umgang mit Möglichkeiten und kreativen Ideen. Der Fragende erhält einen Einblick in die Denk- und Verhaltensmuster der Befragten.”
(Brunner, 2017, p. 44)

For the expert interview, 14 German questions have been asked. Some questions are altered from the questionary the volunteers received and some questions aimed to get answers based on the results of the first six interviews.

3.3 Interviews

The interviews have been held either via telephone or in person. Even though the volunteers had already been informed about the content of the interview beforehand, they got another introduction to the topics of this thesis right before the interview started. They were told to talk freely and ask if any question is unclear. Afterwards, the audio recording started and the volunteers gave their consent that the interview data could be used for this thesis in a pseudo anonymous form. On average, the duration of the interviews was about 15 minutes and every question could be answered. Each volunteer got the interviewer's contact details, in case more questions about the interview or the thesis came up.

Every recording was transcribed into grammatically corrected standard German; however, the content has not been changed.

The expert interview was held via e-mail conversation and 12 out of 14 questions could be answered.

4 Results

In Europe there are lots of different blood glucose meters on the market. They come in different sizes, shapes, colours and with different features. Some of them do have disability access and some do not. This chapter deals with the results of the user interviews regarding their health backgrounds, their blood glucose meters, the devices' accessibility and their future visions. Furthermore, this chapter includes a translated version of the expert interview.

4.1 User Interviews

The following subchapter gives an insight into the everyday lives of six visually impaired people with diabetes and how they deal with their blood glucose meters, as well as their wishes and ideas for the future.

4.1.1 About the Volunteers

There are three male and three female volunteers who took part in this interview process. Three volunteers live in Austria and three live in Germany. There is a wide range of ages as the youngest is 28 years old and the oldest is 71 years old. The average age has been calculated at 52,3. Five out of the six respondents stated that they suffer from type 1 diabetes and only one from type 2 diabetes. Those with type 1 got diagnosed between their 1st and 22nd year of life. The average age when they got diagnosed was 12. The volunteer with type 2 got diagnosed at the age of 40. One of the volunteers lost her sight due to congential glaucoma in her as a baby. The others went blind due to diabetic retinopathia at different times of their lives. One went blind at the age of thirteen, two in their mid twenties and two in their early forties. Two respondents went blind in the same year they got diagnosed with diabetes. The other three respondents had about 20 years between their diagnoses and blindness. The HbA1c levels of the volunteers range from 6,1 to 8,9, with an average of 7,6. While three volunteers have their blood glucose levels measured continuously, the other three measure their levels three to five times a day. For an overview of this data see Table 1.

Table 1 Quantitative Data Overview (DR = diabetic retinopathia)

Interview	**1**	**2**	**3**	**4**	**5**	**6**
Age	52	28	55	71	57	51
Sex	female	female	male	male	male	female
Country	Austria	Austria	Germany	Germany	Germany	Austria
Diabetes type	1	1	2	1	1	1
Reason for blindness	Congenital Glaucoma	DR	DR	DR	DR	DR
Age of blindness	0	13	40	23	43	25
HbA1c	7,6	8,9	7,1	6,1	7,8	8,5
Current blood glucose meter	Wellion Calla Dialog	Wellion Calla Dialog	Accu-Chek Mobile	Dexcom G4	Freestyle Libre	Freestyle Libre
Other used blood glucose meters	Gluki Plus, GlucoTalk	some speaking devices	Accu-Chek Voicemate OneTouch	Accu-Chek	Contour	Gluki GlucoTalk OneTouch
Satisfaction with the current device	4	4,5	5	3	4	5
Menu navigation	3	3	2	1	5	1

4.1.2 About the Glucose Meters

The first question from the block about blood glucose meters was about the device the volunteers are using at the moment. Three people mainly use continuous glucose monitoring sensors, two people use a blood glucose meter with test strips and one with a test cassette. One person with a continuous glucose monitoring sensor also uses a device with test strips. The blood glucose meters the volunteers are using at the moment are the Calla Dialog from Wellion[1] (see Figure 6), the Accu-Chek Mobile[2], the G4 from Dexcom[3], the Accu-Chek Compact Plus (not available any more) and the Freestyle Libre from Abbott[4] (see Figure 7). Throughout their lives the respondents went through a lot of experiences with their blood glucose meters. Other devices they used to work with in the past are the

[1] http://www.wellion.at/de/produkte/blutzuckermessgeraete/wellion_calla_dialog/

[2] https://www.accu-chek.at/blutzuckermessgeraete/mobile

[3] https://www.dexcom.com/dexcom-g4-platinum-share

[4] https://www.freestyle-diabetes.at/produkte/freestyle-libre/

GlucoTalk from Alere[5] (which is owned by Abbott), the GlukiPlus from Caretec (not available any more), the Accu-Chek Voicemate (not available any more), a device from OneTouch[6] and one of the Contour devices from Bayer[7].

Figure 6 [Wellion Calla Dialog, a blood glucose meter with voice output] (2010). Retrieved from http://www.wellion.at/de/produkte/blutzuckermessgeraete/wellion_calla_dialog/

The next question was "How did you get your current device? Has it been recommended or did you research it on your own?". Two volunteers got their devices via recommendation. One got it recommended from her treating doctor and the other one from a friend. The other volunteers found their devices through online articles, online platforms and phone calls with companies that provide blood glucose meters with voice output.

To get to know the preferences of the volunteers regarding their devices, the next questions asked for their favourite, their second favourite and their least favourite function of their device. In general, the most important function was the voice output. Two volunteers stated that it was their favourite function and two their second favourite. Other favoured functions are the alarms for hyper- or hypoglycemia, the freedom to access their measurements when- and wherever they want, to not have to sting their fingers for each measurement, to measure their blood glucose level without test strips but with a cassette, to be able to

5 https://www.alere.com/de/home/product-details/glucotalk.html

6 https://www.onetouch.de/

7 https://www.diabetes.ascensia.at/

personalize the device with various options, as well as having a device that adjusts itself, to have exact measurements and to know the battery level. For one volunteer the least favourite function is the memory, because the voice output does not work with the memory of the device. Another least favourite is the display since it can not be read by the volunteer any ways. One more unnecessary function, as one volunteer stated, is the voice options where one can choose between a male or female voice. Two respondents shared the same opinion on their least favourite function, even though it can not really be called a function but a feature: they do not care for shape, size or design of the device. The last respondent did not have any least favourite function since the device she uses is quite new and she did not notice anything negative so far.

For an overview of all answers see Table 2.

Table 2 Questions and answers about the glucose meters

Question / Volunteer	1	2	3	4	5	6
Which blood glucose meter are you using at the moment?	Wellion Calla Dialog	Wellion Calla Dialog	Accu-Chek Mobile	Dexcom G4	Freestyle Libre Link	Freestyle Libre Link
Which devices have you used in the past?	Gluki Plus GlucoTalk	One device without voice output and two devices with voice output.	Accu-Chek Voicemate, OneTouch	Accu-Chek	Contour	GlucoTalk, Gluki Plus, OneTouch
How did you get your current device? Has it been recommended or did you research it on your own?	Self-research, I called a diabetes care company.	It was recommended from my doctors. I wanted one of those devices you wear on your upper arm, but they are not available with voice output yet.	Self-research	Through a web forum called Diabeticom.	Through an online article about the Freestyle Libre having an IOS application with voice output.	A friend recommended it to me.
Which is your favourite, your second favourite and your least favourite function of your device?	1st: voice output 2nd: low battery warning Least: voice settings	1st: accurate measurements 2nd: voice output Least: the memory, since I cannot use it anyway	1st: no test strips 2nd: audio output Least: form, size, look of the device	1st: alarm for high blood sugar levels 2nd: alarm for low levels Least: the display, since I cannot use it anyway	1st: voice output 2nd: that the settings can be changed and accustomed by me Least: the looks of the device	1st: not have to prick yourself 2nd: measurements available at any time and no worries about test strips Least: there is nothing unnecessary

4.1.3 About the devices' accessibility

The following question is about the accessibility of the blood glucose meters the volunteers are using. Three out of six respondents use devices that are, on their own, not accessible for blind or visually impaired people. However, two out of those three can use their devices with a mobile application which works with voice output. The third respondent is in need of his seeing wife to get to know his blood sugar levels. He is well aware that a mobile application exists which would work with his device, but does not want to own and use a smart phone. Another respondent is using a blood glucose meter that is peeping the digits of the measurement in ones, tens and hundreds. The last two respondents use devices with voice output. Nevertheless, the voice output is not applicable with all functions of the blood glucose meters.

Figure 7 [Freestyle Libre application for smartphones with the LibreLinkUp system] (2018). Retrieved from https://www.freestyle-diabetes.at/produkte/freestyle-libre/

To check if the devices do have some functions to let them know about the actions the volunteers are entering, the next question was "How do you know if your input has been entered?". One person simply said that he does not get any feedback at all. The other five respondents claimed that their devices are peeping when they enter something and some also talk and say "entered".

Another question about accessibility was "How do you know about older measurements?". Three people said that there is no way to get to older measurements, since the voice output does not work with the memory options.

They have to type their measurements into a computer file, write them down or remember them to know their last blood glucose levels. One claims that the device is peeping the measurements and two can retrieve their blood glucose levels from the last eight hours via mobile application, but one of those two has not figured out yet how to get there in the menu.

To get a good overview of data that changes throughout the day curves and diagrams are a good way for people to understand their data. Nevertheless, if those curves and diagrams can not be read, other solutions have to be found. The volunteers were asked if they would like to have an overview of their last measurements e.g. in form of an audio curve where high blood glucose levels can be heard as a high tune and low measurements as a low tune. Four out of six volunteers do like the idea of an audio curve or other ways of getting an overview. One stated that this would help with the regulation of his basal insulin dose and another one said that they would love to hear the measurements via voice output as well. The last two claimed that they would not need such an overview or audio curve, as long as they had their last measurements told via voice output or peeping.

For an overview of all answers see Table 3.

Table 3 Questions and answers about the devices' accessibility

Volunteer / Question	1	2	3	4	5	6
How is your device adapted to your visual impairment?	Voice output	Voice output, but not in the menu.	It is peeping the digits in hundreds, tens and ones.	It has alarms when the blood sugar levels are out of the normal range, but my wife has to read them.	The device itself is not usable for blind people but the mobile application works with voice output.	The reading device is not accessible for blind people but the mobile application works with voice output.
How do you know if your input has been entered?	Through voice output and signal tunes	Via signal tune	Via signal tune	Not at all.	Through voice output, but only on the mobile application.	Via voice output on the mobile application and signal sounds.
How do you know about older measurements?	I have to listen to them on the computer since the device does not read them.	I write them down manually and my friends and family read them to me.	Via signal tunes	Not at all. But I do not need them, I roughly remember my measurements of the same day.	In the mobile application via voice output.	I have to yet find out.
Would you like to have an overview of your last measurements e.g. in form of an audio curve?	I would rather have voice output, but I would also like an audio curve.	Yeas, that would be helpful.	No, I am not in need for it.	Yes, that way I could see how I would need to change my basal insulin doses to get better results.	Yes that would not be bad.	I would rather have each measurement.

4.1.4 Usability and Menu Navigation

The following question was a scaled question and asked how satisfied they were with their devices. 5 meant very satisfied and 1 meant very unsatisfied. Two people chose 5, one chose 4,5 two chose 4 and one chose 3. Then they were asked: "What could be better?" The answers of those with blood glucose meters that measure with test strips or cassette were very similar. They would like to have voice output that works on all the functions of their devices, including the menu and memory. Those with continuous glucose monitoring sensors had rather different ideas of improvements. One would like to have a voice output function on the scanning device that comes with the sensor and not just on the mobile application. Another would like to have easier navigation through the menu on the mobile application to also get to older measurements. The third person who is also using a sensor, could not think of any improvements.

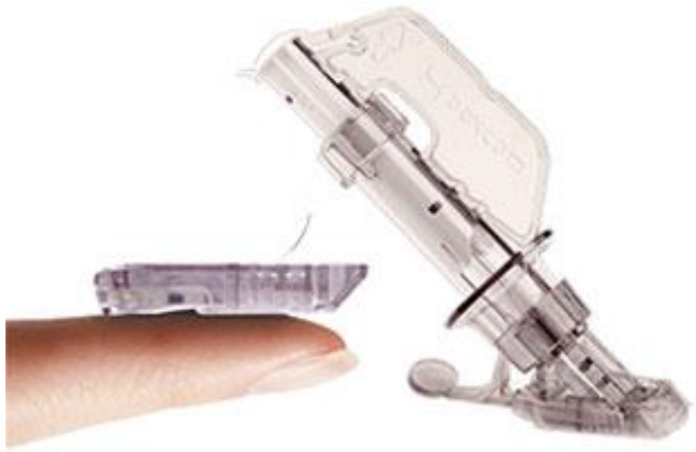

Figure 8 [Dexcom G4 sensor and applicator] (2016). Retrieved from https://www.nintamed.eu/p/products/dexcomg4/sensor

The next question is: "Does your device have explanations and tips that can help in specific situations?" Four volunteers say no, unless they google it, or ask someone that can see and read it from the display or can read the manual. Two say that their device does tell them their blood sugar level trends. That means the device can tell if their levels are rising or sinking. "How easily can you navigate through the menu?" was the next scaled question. 5 meant very easy and 1 meant very difficult. Only one respondent answered this question with a 5, very easy. Two answered with a 3, one with a 2 and two respondents find it very difficult to navigate through the menu and chose 1. Someone who can read the display and sees the change of buttons and switches in the menu when navigating through it would not wonder if their order has been entered or not because they see if something has changed or not. For blind or visually impaired people, however, it might not always be as clear.

To check the susceptibility to errors, the volunteers were asked about the frequency of errors. Three people did not experience errors with their devices and one said that there are no errors with the mobile application but with the screening device that comes with the sensor. The volunteer had to wait for ten minutes until the screening device could be used again after the error has shown. The last two do experience errors regularly, the first one 1-2 times a month and the second one mainly in the colder months due to cold hands that lead to less blood circulation. Next, the respondents were asked if their measurements were saved, and for how long. All respondents agreed that their measurements are saved, some say for eight hours, some say a few hundred measurements and some did not know how many or for how long they are saved.

The last question of this block was about the handling of the devices. That includes the stinging, inserting the test strips, applying the sensors, changing the needles, and so on. The volunteer that is using the test cassette has no problems at all, but stated that inserting the test strips from his former device was very difficult. The other two respondents with blood glucose meters that work with test strips do not have any problems with inserting the strips, one just claims that there is not enough blood on the test strip occasionally. Those with continuous glucose monitoring sensors on the other hand do have difficulties to apply their sensors. (See Figure 8) One gets his sensor changed by his seeing wife, one can apply the sensor but needs help with injecting it and the third one can do it by himself, but stated it to be difficult especially with older people.

For an overview of all answers see Table 4.

Table 4 Questions and answers about usability and menu navigation

Volunteer Question	1	2	3	4	5	6
On a scale from one to five, how satisfied are you with your device? 5 = very satisfied and 1 = very unsatisfied.	4	4 to 5	5	3	4	5
What could be better?	There is no voice output on the memory function, I have to type the measurements into the computer.	That the memory works with the voice output.	A menu navigation that work with voice output.	Voice output and a smaller sensor.	I cannot tell since I am using this device for not very long.	The menu navigation.
Does your device have explanations and tips that can help in specific situations?	No, I have to take my mobile phone and google it.	No, there is just a written manual.	No.	Yes, some. But I do not know about them unless my wife reads them to me.	Yes, it has a trend curve with voice output. It tells me if the blood sugar levels rise, decrease or stay the same.	No, it just tells me my measurements and trends.
How easily can you navigate through the menu? 5 = very easy and 1 = very difficult.	3	3	2	1	5	1
Do errors occur? If they do, how often?	Yes, if there is not enough blood on the test strip. More often in colder seasons.	Not yet.	Yes, 1-2 times a month.	No. It only shows stars when it is out of reception. That happens about once a month.	Not yet.	On the mobile application not, but the reading device reported sensor errors.
Are your measurements saved, if yes, how many?	Yes, but I do not know how many.	Yes, I think a few hundred measurements.	Yes, but I cannot say how many.	Yes, every five minutes.	All measurements are saved.	Yes, all within eight hours.
Do you have problems when using your device? E.g. the stinging, inserting the test strips, applying the sensors, changing the needles, etc.	I do not have any problems.	No Problems at all. But occasionally there is not enough blood on the test strip.	It is easy to use with the test cassette. But with the test strips it was very hard to use.	My wife is in charge of all of that.	It is easy to use. But changing the sensor can be problematic and is easier with the help of a seeing person.	I can not inject the sensor myself. I can set it, but for injecting I need someone's help.

4.1.5 Future Visions

The volunteers were asked to imagine a future with no boundaries regarding technology. They were supposed to list all the features a glucose meter should have to make it perfect and ideal for them. The most common one was the desire for a chip or a sensor that continuously measures their blood glucose levels and uses the measurements to calculate the right amount of insulin one would need at the moment. This sensor/chip could also be connected with an insulin pump. That way all the measuring and calculation would be done automatically. Some would not even mind having the chip fully transplanted under the skin, so they would not have to bother to change it regularly. Others want to be in control of the amount of insulin they are injecting but wish for a system that warns them in case of hyper- or hypoglycemia. Another common vision was that all devices should be accessible for blind people via voice output. One volunteer also wished for some kind of interface for blind and deaf people, so they could read their measurements via Braille, as well as to get more accurate measurings.

The final question asked for remarks, wishes and ideas to make blood sugar measuring easier and more accessible for visually impaired people. Most volunteers wished for more devices with voice output that works even in the menu and the storage. Some also stated that there should be better solutions for blind or visually impaired people to measure their blood glucose levels than with test strips. Due to the strips it is more likely to get errors or make mistakes than with test cassettes or continuous glucose monitoring sensors. One is hoping for skin friendlier patches for the attachment of the sensor and another one mentioned bigger displays for visually impaired people with low vision. A volunteer is using the apple watch and heard about a sensor that is integrated into the watch and measures the blood glucose level through the skin without having to sting it. That technology did not launch yet, but this would be perfect for blind and visually

impaired people, the volunteer stated. The wish of a respondent from an interview that was held in December 2017 was to have the Abbott Freestyle smartphone application available for iOS as well. At that point it was only available for android, but the iOS application launched in February 2018.

For an overview of all answers see Table 5.

Table 5 Questions and answers about future visions

Volunteer / Question	1	2	3	4	5	6
Imagine a future with no boundaries regarding technology. What features should your ideal blood glucose meter have?	A chip that measures blood sugar levels and calculates the right amount of insulin that is needed. Or tendencies for high or low blood sugar levels.	It would have a voice out put and tell you time and date. Also, a chip on the upper arm would be comfortable, so I would not have to prick myself as often and get less horn skin on my finger.	A continuous glucose monitoring device that you wear on you arm. Or combined with an insulin pump. The measurements are calculated into insulin doses and you just have to control it.	It should measure my blood sugar level via voice command and tell them to me via voice output. And for deaf people there should be ways to output it via Braille. Also, the should be more accurate.	It should be accessible and barrier-free by default, so I would not need to laboriously work myself through the menu to turn on the voice output. I could imagine a chip that is implanted under the skin and does not have to be changed every 14 days.	A combination of a blood glucose meter and an insulin pump that calculates and injects the right amount of insulin.
Do you have any remarks, wishes and ideas to make blood sugar measuring easier and more accessible for visually impaired people.	It would be nice to have a mobile application that works with the freestyle chip, so I would not have to prick myself so often.	For example a chip that continuously measures your blood sugar levels and reads them to you.	There should be devices with voice output that not just work on measurements but also on menu entries. And there should be no test strips, but test cassettes to lessen the chance of errors.	There should be voice outputs and big displays by default. Everyone who does not need them can turn them off.	Test strip free devices should be financially supported and as affordable as those with test strips. Also, the band-aids should be more skin friendly.	I like the idea of the Apple-watch, which measures the blood sugar levels via skin resistance. You would not need to be afraid of ripping off your sensor or prick yourself.

4.2 Expert Interview

A product manager from a diabetes department of a global healthcare company was interviewed via e-mail conversation. This is the translated version:

The first question was “How do visually impaired customers get to know of your products?” The expert stated that most customers get their recommendations from their treating doctors, as well as radio advertisements. Institutions for blind and visually impaired people also assist with and support the search for suitable devices. The next question was about which roles health insurances play, regarding the sales and was answered that there is no relation with the insurences and the sales.The expert specified there used to be aspirations from certain health insurance companies to influence doctors to prescribe those devices that are cheaper for the insurances, regardless of the quality. However, the expert assures that this is not happening any more and that it is important that new methods and devices are paid for by the insurances, in order to guarantee that everyone gets what he or she needs.

The following question is partly the same question the volunteers were asked to check if the volunteer’s devices are up to date. “How are blood glucose meters adapted to visual impairments nowadays?” The expert could say that a lot of new technologies have found their ways to this area like voice output. Also, applications and the combination of new measurement technologies provide a lot of new support and assist options. The experts opinion was asked on which device functions would be the most important, the second most important and the least important for visually impaired people. The most important one as the expert explained, is the measurement and that it is readable/audible. The second most important would be easy and accessible handling of the test strips, applying the blood etc. And colourful covers, bags and stickers are the least important features according to the expert.

When asking for improvements of the blood glucose meters, the expert is already very satisfied with the current situation and quality of the devices. But, refered to visually impaired people there could be specific improvements. The expert gave voice command as an example for a better menu navigation. This leads to the next question for ways to improve menu navigation for visually impaired people. Next to the voice command, the expert highlights the importance of a minimalistic menu where the options should be set at the start. That way, no further adjustments are needed later, says the expert, and the data analysis and storage could happen on a computer or tablet, etc. “What errors could occur while measuring the blood sugar levels?” was the next question. The expert stated that the errors are same as with diabetics with normal sight. This includes unclean hands, not enough blood on the test strip/cassette, wrong measurements due to too much pressure, etc. To go into detail about the missing voice output when entering the memory section of many blood glucose meters the expert was asked if there is a reason why only new measurements are spoken. This question could not be answered because the expert's company does not have such devices.

The folling question was asked to find out about new technologies to make curves and data overviews accessible for visually impaired people. The expert referred to magnifying vision aids and reading devices to help those that have low vision and stated that those devices are very expensive and should be more supported by health insurances. But the expert could not think of technologies for blind people. Since the volunteers wished for blood glucose devices have a voice output by default and can be turned off if not needed, the expert was asked why this is not available in every device. The expert explained that every technical detail costs money in the development and is one more source of error. Furthermore, the trend is moving towards simplicity and away from having all functions available that have to be turned off later, according to the expert.

"Do you personally think that all medical devices that are used by patients themselves should be barrier-free?" was the next personal question. The expert negated it and said "in my opinion there should be barrier-free medical devices in all areas, but not all medical devices should be barrier-free. A sportsman gets a medical device that is suitable for sports activities and visually impaired people get a medical device that helps them with their special needs." Asking for ways to make the handling of the device easier for visually impaired people, the expert stated that the handling should be omitted or so minimal and seldom that this will be no problem any more.

As with the volunteers, the expert was asked to imagine a future with no boundaries regarding technology and what features the perfect blood glucose meter should have. The answer was that in the future, there are no blood glucose meters any more because the technology is improving so fast right now. The expert believes that every diabetic, also those with visual impairment, will have it easier to manage their diabetes. The last question for remarks, wishes and ideas to make blood sugar measuring easier and more accessible for visually impaired people has not been answered.

For an overview of all answers see Table 6.

Table 6 Questions and answers from the expert interview

Questions	**Answers**
How do visually impaired customers get to know of your products?	Most customers get their recommendations from their treating doctors, as well as radio advertisements. Institutions for blind and visually impaired people also assist with and support the search for suitable devices.
Which roles do health insurances play, regarding the sales?	With the sales directly, none. There used to be aspirations from certain health insurance companies to influence doctors to prescribe those devices that are cheaper for the insurances, regardless of the quality. However, nowadays this is not happening any more. It is important that new methods and devices are paid for by the insurances, in order to assure that everyone gets what he or she needs.
How are blood glucose meters adapted to visual impairments nowadays?	A lot of new technologies have found their ways to this area. Speaking devices have been available for a long time now, but with applications and the combination of new measurement technologies there are a lot of new support and assist options.
In your opinion, which device functions are the most important, the second most important and the least important for visually impaired people?	Most important is, the measurement and that it is readable/audible. Second most important would be easy and accessible handling of the test strips, applying the blood etc. And the least important features are colourful covers, bags and stickers.
What could be better about nowadays' blood glucose meters?	In general, the quality of current devices is extremely good, regardless of the company. They are available in all kinds of shapes, colours, levels of functionality and sizes. To refer this question to visually impaired people, there are some specific improvements, like voice command, to make menu navigation easier.
Are there ways to improve menu navigation for visually impaired people?	As mentioned above, the voice command. Second, a minimalistic menu. The options should be set at the start, so no further adjustments are needed later. The data analysis and storage could happen on a computer or tablet, etc.
What errors could occur while measuring the blood sugar levels?	Same as with diabetics with normal sight: unclean hands, not enough blood on the test strip/cassette, wrong measurements due to too much pressure, etc.

Is there a reason why there are devices with voice output where only new measurements are spoken, but the rest of the menu, storage, etc. has no voice output?	This question cannot be answered, because our company does not have such devices.
Do you know technologies to make curves and data overviews accessible for visually impaired people?	There are many magnifying vision aids and reading devices to help those that have low vision. Nevertheless, those devices are very expensive and should be more supported by health insurances.
Why do not all blood glucose devices have a voice output that can be turned off if not needed?	Every technical detail costs money in the development and is one more source of error. The trend is moving towards simplicity and away from having all functions available that have to be turned off later.
Do you personally think that all medical devices that are used by patients themselves should be barrier-free?	No, in my opinion there should be barrier-free medical devices in all areas, but not all medical devices should be barrier-free. A sportsman gets a medical device that is suitable for sports activities and visually impaired people get a medical device that helps them with their special needs.
Are there ways to make the handling of the device easier for visually impaired people?	The handling should be omitted or so minimal and seldom that this will be no problem any more.
Imagine a future with no boundaries regarding technology. What features should the perfect blood glucose meter have?	In the future, there are no blood glucose meters any more. No finger pricking, no blood application, etc. The technology is improving so fast right now, every diabetic, also those with visual impairment, will have it easier to manage their diabetes.
Are there any remarks, wishes and ideas to make blood sugar measuring easier and more accessible for visually impaired people?	-

5 Discussion and Conclusion

Looking at the results, it shows that most volunteers are quite satisfied with their current devices, as they gave an average rating of 4,25 out of 5. (See Figure 9) However, they do still have many suggestions for improvement. When it comes to the accessibility of the menu navigation, the ratings were not as great. The average rating was 2,5 out of 5.

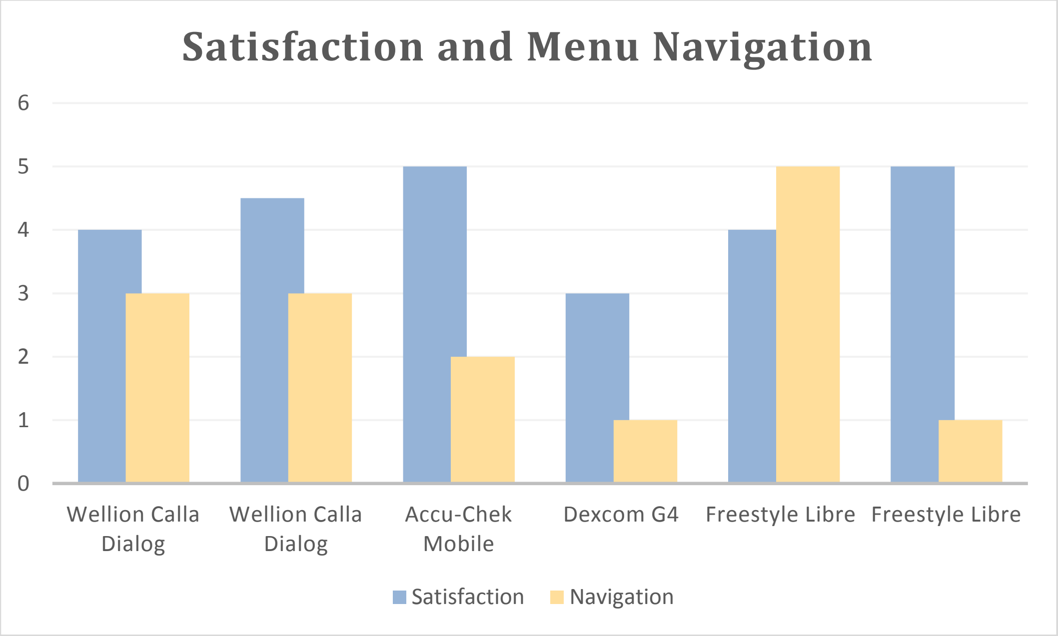

Figure 9 The volunteers' satisfaction and assessment of the menu navigation regarding their own blood glucose meters. 1 indicatesnot satisfied/very difficult to navigate, 5 indicates very satisfied/very easy to navigate.

So, what interface requirements do visually impaired people have when measuring their blood sugar levels? The first and most important feature is the voice output, or at least an audio output. For visually impaired and blind people audio output is the fastest and most effective way to gain information. Second, the haptic component. Two volunteers with a continuous glucose monitoring sensor additionally use a mobile application to get to their blood sugar levels. The screening device that comes with the sensor is not accessible for blind or visually impaired people, so they need to use their smartphones. Smartphones with a touchscreen are very visual, since there is a flat screen with few or no buttons that can be pressed. That is where haptics come into play. There are many new studies that try to achieve haptic representation of 2D and 3D data. In 2014 Wiertlewski et al. presented a high fidelity surface haptic device that uses ultrasonic vibrations to control the friction of the finger when sliding over a glass plate. Depending on the amplitude of the ultrasonic vibrations, the user can feel different strengths of roughness, while a non-contact sensor detects the position of the finger. (Wiertlewski, Leonardis, Meyer, Peshkin, & Colgate, 2014, p. 241 ff.) Ultrahaptics[8] takes this technology one step further, as they have developed a pad which also sends ultrasonic vibrations into the air above. When holding a hand over the pad, shapes, waves and forces can be felt. A sensor with gesture recognition tracks the hand and gives real time feedback. That way, the user can feel e.g. a regulator or button that changes the volume of sound, colour, or whatever else is needed to be regulated while "pressing" or sliding through the air. (Ultrahaptics, n.d., p. 2 ff.)

This technology could be used on screens and displays to let blind or visually impaired people feel their blood sugar measurements as well as diagrams and curves to present them data overviews. Other methods to make visual data accessible to blind and visually impaired people that were described by Fritz et al. are through a tactile image enhancer combined with a software that simplifies pictures and a haptic graphing system, using the PHANToM[9]. The first method uses a tactile image enhancer which is a device that works with a specific type of paper and a wax pen that react together when heated. All lines, dots and spaces that were written on the paper with the wax pen will be enhanced after the device has heated the paper. A software was developed that uses algorithms that simplified pictures of faces, a hot air balloon and an illustration of a human heart. A pilot study, using different algorithms, showed that when edge detection was applied first, followed by segmentation, 97% of the pictures could be matched together correctly. The second method uses the PHANToM device which is a haptic device with a robotic arm that can send force to a fingertip or a pen that is attached to the robotic arm. This allows the user to feel 2D and 3D objects like line graphs, curves, as well as spheres and boxes. (Fritz, Way, & Barner, 1996, p. 2 ff.) The expert stated: "The menu navigation should be as simple and minimalistic as possible. Options should be set at the beginning so that there is no navigation necessary later on. For the data analysis and storage, computers and tablets can be used." This would also correspond to the statements of the volunteers who wished for devices that can be set and adjusted easily right from the start. But, here is also where the opinions of the two parties divide up. While the volunteers wish for those easy settings and adjustments to be accompanied by voice output

[8] https://www.ultrahaptics.com/

[9] http://www.delfthapticslab.nl/device/phantom-omni/

by default on every medical device, the expert sees no necessity in equipping every medial device with voice output since every additional technical component costs money in the development. Also, the expert sees no point in having lots of different features in one device and rather sees a future of devices that fit the individual needs of the customer.

How are the blood glucose meters corresponding to those requirements? Right now, common blood glucose meters used by visually impaired and blind people only have audio output like signal tunes and voice output. For most interview respondents this would be enough, if the voice output would work on the whole device and not just on some functions. Unfortunately, the expert could not answer the question if there is a reason why the voice output would not work on all functions of the device. However, the expert stated that voice commands would be a good solution to help with the menu navigation. If we can tell Alexa[10] to turn on the music in our homes, why not tell our blood glucose meters to change the time options or read the last measurements? Many of the volunteer's future visions do not seem to be that utopistic. Sensors that continuously measure the blood glucose levels are already available and insulin pumps as well. Why not combining those two? The expert also shares that vision of blood free measuring and better accessibility of the devices.

Where are the difficulties of common data distribution for visually impaired people? First of all, most data is distributed visually, especially when it comes to medical data. Not all devices are accessible for visually impaired people and if they are, they might not be as accessible as they claim to be as we heard previously. Most pictures' content is not available unless they own some sort of software that uses metadata and image recognition to tell them what actually happens on the picture. Fortunately, this technology is already very advanced and available in app-stores, for example the Aipoly[11] and the Seeing AI[12]. Lidwell et al. pointed out that accessibility means to think of a universal design that can be used by everyone regardless of their disability, knowledge and without modifications. There are four principles to get to this design: 1. Everyone should be able to <u>perceive</u> the design, therefore, multiple layers of data distribution are needed. This can be in form of texts and icons, as well as audio and tactile, e.g. elevator buttons with raised numbers and additional Braille. Perception an also be achieved by tagging pictures and adding metadata to allow assistive software to recognize its content, as

10 https://www.amazon.de/l/12775495031

11 https://www.aipoly.com/

12 https://www.microsoft.com/en-us/seeing-ai/

mentioned earlier in this thesis. 2. Make the design operable for everyone regardless of their disability. This can be achieved by minimizing repetitive actions, lessening the amount of force that is needed to operate the design and making it accessible and usable from various angles and heights. 3. To keep it simple, any unnecessary complexity needs to be eliminated, codes, controls and modes should be similar and consistent and all actions should be feedback-supported. 4. The chance of errors should be minimized to achieve forgiveness. The design should include warnings and confirmations to avoid unwanted actions, as well as the option to undo an unwanted action. (Lidwell, Holden, & Butler, 2010, p. 16)

When looking at measuring devices that not just visually present their data, but also present them in non-visual ways like audio output and haptics, we find those non-visual components as additional help. Nevertheless, these additional components help to understand the measurements and surroundings better than having them presented only visually. The most common use of audio output in measuring devices is as an alarm. Also, audio output serves as feedback to the user. Haptics can as well give feedback additional to visual inputs.

In 2016 a study on laser microsurgeries took place. While it is hard to determine the depth of laser cuts through soft tissue solely visually, Fichera et al. supported the surgeon with vibrotactile haptic feedback during surgery. The combination of visual and haptic input significantly improved the surgeon's precision. (Fichera, Pacchierotti, Olivieri, Prattichizzo, & Mattos, 2016, p. 59)

Another study in 2016 researched on emotional awareness and generating affection through visual and acoustic stimuli compared to visual-haptic and audio-haptic stimuli combined. 19 participants were shown pictures which were rated based on two parameters, arousal and valance, and then pictures combined with haptic stimuli. Some of those combinations were supporting each other in terms or their parameters and some were conflicting each other. Furthermore, they were presented sounds only and then sounds combined with haptic stimuli, again supporting and conflicting each other. (Indurkhya, 2017, p. 5 ff.) The results show that the arousal response is increased when haptic stimuli are added to the visual and acoustic inputs. Nevertheless, regarding the valance parameter, no changes in the response could be found when adding haptic stimuli. (Indurkhya, 2017, p. 7)

To improve the understanding and handling of blood glucose meters and their measurements, audio and haptic could be combined to give visually impaired and blind people the opportunity to experience their devices with more than one sense.

To get a better idea of all the steps it takes to measure your blood glucose levels, the user guides and operation manuals from the blood glucose meters that the volunteers are currently using, have been examined. Starting with the Calla Dialog from Wellion, which was rated mediocre by two volunteers, the first barrierfree service can be heard as soon the blood glucose meter has been turned on because the voice option is on by default (‘Wellion Calla Dialog Handbuch’, 2017). This may sound self-evident, but according to some volunteers, it can be laborious to turn on the voice output for someone who can not see what is showing on the display. The second plus in terms of accessibility is the menu navigation with a rotating wheel (‘Wellion Calla Dialog Handbuch’, 2017, p. 19). The haptic information of rolling the wheel up and down, as well as pushing it like a button is very important for blind or visually impaired people. Voice output and the haptics combined are a good solution of menu navigation for someone who can not read a display. Furthermore, every step is accompanied by a voice output, that way the visually impaired person knows exactly where in the menu he/she is at the moment. In the user guide a table shows every sentence along with its meaning (‘Wellion Calla Dialog Handbuch’, 2017, p. 22). (See Table 7)

Table 7 When and what the Calla Dialog speaks. Retrieved from 'Wellion Calla Dialog Handbuch', 2017, p. 22

WHEN does the device speak	**WHAT** it wants to express
Turned on	Welcoming sound
Invites the user to insert the test strip.	‘Insert the test strip.’
The test strip has been inserted and the device is ready to measure. (blinking arrow and blood drop symbol)	‘Blood sugar test. Please apply blood onto the test strip.’
The test is finished and the result shows on the display.	‘Your blood sugar measurement is (number) milligram per decilitre.’

A big complaint about the Calla Dialog from Wellion was the lack of voice output when it comes to recalling older measurements.

Following the instructions from the user guide, the voice output follows the navigation until the menu entry ‘mem’ is chosen and says ‘memory retrieval’. Nevertheless, once the user is in the memory option the measurements are only shown on the display without any voice output. (‘Wellion Calla Dialog Handbuch’, 2017)

The next blood glucose meter, the Accu-Chek Mobile, was rated two out of five in terms of menu navigation. This device works with a test cassette, which was the volunteer's favourite feature. The cassette allows any user to measure their blood sugar levels without inserting test strips. This can reduce sources of errors, like inserting it the wrong way, especially for visually and blind people.

A big drawback is that the acoustic setting is turned off by default. Since there is no voice output, blind and visually impaired people can only activate the acoustic setting with the help of a person with normal vision to navigate through the menu. When the device is turned on, a signal sound can be heard when a test field is moving to the tip of the cassette, the device is inviting the user to insert blood on the test field, the measurements is running, the measurement is showing on the display and four double sounds appear when an error is showing. However, there are no sounds when entering any menu entries, which leaves a blind person in uncertainty if the action has been entered or not. ('Accu-Chek Mobile Gebrauchsanweisung', 2012, p. 48) Once the acoustic setting is turned on, every measurement is issued in peeping sounds in the digits of hundreds, tens and ones. This way of audio output must be learned accurately and, at the beginning, also be controlled by a seeing person to reduce errors. Also, with a turned on acoustic setting high tuned signals can be heard when the battery is low, the test cassette is empty or an error is shown, as well as before the measurements are issued. ('Accu-Chek Mobile Gebrauchsanweisung', 2012, p. 81 ff.) The Accu-Chek mobile can be operated with three buttons. (See Figure 10) There are two buttons with arrows pointing up and down to navigate through the menu and one button to turn the device on, off and press enter. Even though there are only three buttons, two of them are not distinguishable because they both sit below to the on/off button and have their arrows only printed on but not raised. ('Accu-Chek Mobile Gebrauchsanweisung', 2012, p. 9) Furthermore, even tough errors are signalled with a low tune, there is no way to differentiate them since they are only shown on the display. ('Accu-Chek Mobile Gebrauchsanweisung', 2012, p. 83) Therefore, a blind or visually impaired person can only acquire this information with the help of a seeing person to read the error message on the display. To sum up, it can be said that once the device's stats are set by a seeing person and the acoustic setting is turned on, a blind or visually impaired person should be able to handle it well, if the acoustic mode is trained and understood. However, without help the device is not accessible for the people mentioned above.

Figure 10 [Accu-Chek Mobile] (2017). Retrieved from https://www.accu-chek.be/fr/les-lecteurs-de-glycemie/mobile

The following device has no audio output or any other function to help with visual impairments. The Dexcom G4 is a continuous glucose monitoring device that is built for people with normal vision. This is why the volunteer rated it so poorly (one out of five in terms of navigation) and stated that it can not be used without help from a seeing person.

The device consists of three main components, a sensor, a transmitter and a receiver. The first step is to connect the transmitter with the receiver, which requires the input of a code. After that, various settings have to be entered, like time and language, which only show on the display. ('Dexcom G4 Platinum Bedienungsanleitung', 2014, p. 15 ff.)

The next step is to insert the sensor. For that step the area where the sensor will be inserted has to be cleaned and disinfected. The sensor applicator has to be set onto the disinfected area while being careful not to touch the sticky parts of the band-aid. Once the sensor is set, the safety interlock has to be removed and the button at the end of the applicator can be pushed to insert the sensor under the skin. After the applicator has been removed the transmitter can be snapped onto the sensor, while being careful not to touch the metal parts from the transmitter. ('Dexcom G4 Platinum Bedienungsanleitung', 2014, p. 38 ff.)

The transmitter can now be connected with the receiver. Therefor, menu navigation is required which, as mentioned above, only shows on the display. After a starting time of two hours the sensor adjusted to the surrounding tissue and can be calibrated. ('Dexcom G4 Platinum Bedienungsanleitung', 2014, p. 42 ff.)

Another big disadvantage of this device is that you need to calibrate it twice a day and for the calibration another blood glucose meter is needed. Every twelve hours the blood glucose levels measured with the extra device have to be typed into the Dexcom G4 while using the up/down buttons. Once calibrated the device measures every five minutes and shows the results on the display with a diagram. ('Dexcom G4 Platinum Bedienungsanleitung', 2014, p. 49)

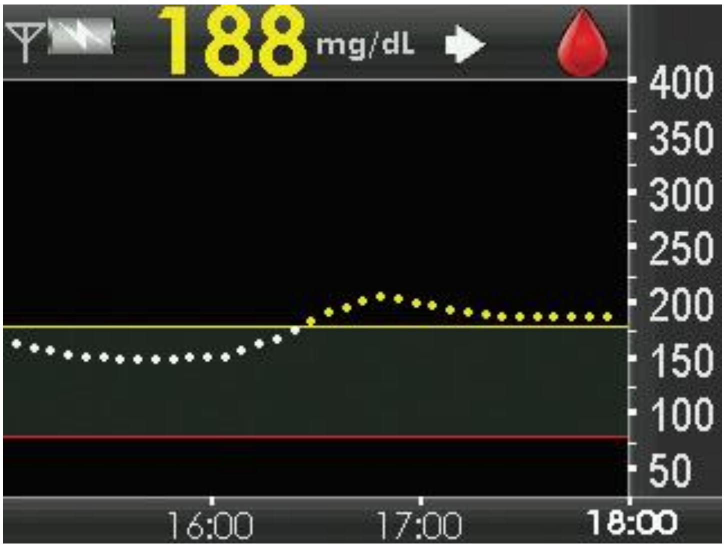

Figure 11 [The Dexcom G4 reading device display showing the current blood glucose level, as well as an overview oft he last three hours of measurements] (2014). Retrieved from Dexcom G4 Platinum Bedienungsanleitung, p.58

The user can choose between a 1, 3, 6, 12 and 24 hour diagram that shows every measurement as a dot, as well as an area that shows the normal range blood glucose levels should have, including warnings when the measurements are outside of that range. (see Figure 11) Furthermore, the diagram includes trend arrows that indicate rising or dropping blood glucose levels. ('Dexcom G4 Platinum Bedienungsanleitung', 2014, p. 58 ff.)

In terms of warnings, there is a way to differentiate them once you know their meanings. Is the measurement above the normal range the device starts to vibrate twice and then a signal tune and vibration combination can be heard two times every five minutes until the measurement is confirmed or the blood glucose level is within normal range again. Is the measurement below the normal range the device vibrates three times and then also goes off every five minutes. If the measurement is very far below the normal range the device vibrates four times and notifies the user with a four-time signal tune and vibration combination every five minutes. The other warnings, like the trend arrows or when the transmitter and receiver are too far apart and can not communicate with each other, only appear on the display, but do not have any signal tunes or vibration warning by default. However, the user can change between warning settings to have the device vibrating when the trend arrows are showing, even though without a look at the display can not differentiate between e.g. rising blood glucose levels and a measurement that is above the normal range since they have the same manner of vibration and signal tune warnings. ('Dexcom G4 Platinum Bedienungsanleitung', 2014, p. 67 ff.)

The display diagram is simple and easy to understand and gives a good overview of the last measurements. Unfortunately, all the numbers, curves and trend arrows can not be seen by visually impaired people which makes them useless for them. Also, almost every step from setting the sensor to calibration to reading the measurements can not be done without the help of a seeing person.

The final device is used by two volunteers and was rated very differently regarding the menu navigation. One rated the Freestyle Libre with a five out of five and the other one with a one out of five. Both use this continuous glucose monitoring device with a mobile application since the device itself is not accessible for visually impaired people. As with the Dexcom G4, the Freestyle Libre has a sensor set which combines sensor and transmitter and a reading device which acts as a receiver and an autonomous blood glucose meter.

At first the reading device has to be set, which works with a touch screen and no voice output. After that, the sensor can be inserted. Therefore, the skin has to be disinfected, the sensor pack and the applicator connected while aligning two black lines and pressed onto the disinfected skin. (See Figure 12) Now, the sensor has to be connected to the reading device by scanning the sensor which is done by holding the reading device next to the sensor within the range of four cetimetres. This triggers the device to make a signal tune sound once the sensor is activated. ('Freestyle Libre Benutzerhandbuch', 2017, p. 18 ff.)

Figure 12 [Markings on the sensor pack and applicator which have to be aligned] (2017). Retrieved from Freestyle Libre Benutzerhandbuch, p. 18

Since the volunteers use the mobile application instead of the reading device the following navigation insights come from the Freestyle Libre Link application, which can be downloaded for free at the mobile app-store. After going through a registration and intros on how to insert and activate the sensor the application lets you choose from several menu entries and application settings. So far, no voice output or audio feedback could be heard. The menu entries include reminders, protocol, a daily pattern, time within normal range, events with low blood glucose levels, a glucose average, a daily diagram, an estimated HbA1c, the usage of the sensor and an entry to share the measurements with other applications. In the application settings the measuring unit, the range within the measurements should be, the carbohydrate units, the signal sounds and lastly the text to speech can be found which was off by default. With the text to speech option activated, there was still no voice output on any intro or menu navigation. The option only works to read the current measurement and direction of the trend arrow.

This might explain why there are two such different opinions on the menu navigations. When it comes to measuring blood glucose levels on a regular basis it is fairly easy to do, the user just needs to hold the mobile phone next to the sensor and the applications reads the measurement. But, navigating through the menu and application settings can be hard and confusing without voice output unless the user has another application that reads everything out loud that can be seen on the display. On the other hand, some menu entries like the diagrams and curves can not be used by visually impaired or blind people anyway. In terms of sensor application and activation the Freestyle Libre might be easier to handle by someone who is blind or visually impaired than the Dexcom G4, but still requires normal vision in some steps, like aligning the lines when connecting the sensor pack with the applicator.

Even though the expert thinks that medical devices should be designed to fit individual groups of people, like sportsmen, disabled people, older people, etc., the researcher’s opinion is that all medical devices should be accessible right from the start. When turning on a new device, a question with additional voice output could appear to ask if one would want to proceed with disability access or standard access. Those barrier-free features should work on and help through all menu entries of the device. Also, money should not be the hindrance of barrier-free medical devices.

6 Summary

The purpose of this thesis is to disclose the problems that occur for visually impaired people when they are measuring their blood sugar levels. The problem is that most medical devices use displays or monitors to present their data and measurements. However, those displays and monitors are not useful for visually impaired and blind people. Therefore, this thesis seeks out the features and user interface requirements that visually impaired people need and would like to see in the future.

Different subject areas were described, such as the types of diabetes, their therapy and how the blood glucose level is measured. Also, different diseases that can lead to visual impairment, sectioned into congenital diseases and acquired diseases, were explained, followed by an overview of data presentation and the history of visualization.

The research questions are as follows:

- What interface requirements do visually impaired people have, when measuring their blood sugar levels?
- How are the blood glucose meters corresponding to those requirements?
- Where are the difficulties of common data distribution for visually impaired people?

To answer those questions, interviews with visually impaired people that measure their blood sugar levels on a regular basis have been held. As an inclusion criterion, their reduction of vision had to be advanced enough, so they were not able to read the blood glucose meter's display any more. Since the interviews were held via phone or in person, the exclusion criteria were deaf, mute and deaf-mute people. The questionary includes 23 questions and is sectioned into the topics health background, blood glucose meters and data presentation, as well as future visions. Since the volunteers were recruited from Austria and Germany, the interviews were held in German. Via social media groups, institutions for blind and visually impaired people and personal contacts, six volunteers could be found. The interviews took about 15 minutes and were transcribed into standard German. Also, an expert interview was held with a product manager from a diabetes department of a global healthcare company.

Three volunteers are from Austria and three from Germany, three are male and three female. Their ages range from 28 to 71 and 5 out of 6 suffer from type 1 diabetes. All but one lost their vision due to diabetic retinopathia. They got their blood glucose meters via recommendations and research and are overall quite satisfied with them. Nevertheless, only three devices are accessible on their own, two devices need an additional application to make them accessible and one volunteer uses a device without any other output than the display. A big problem is the navigation through the menu. Some devices do have an audio output that helps the volunteers to hear if their action has been entered, some, however, do not offer the user any information on this part of the process. Even those devices with voice output would not work on all menu entries. This is why the volunteers wish for blood glucose meters that can talk to them in any menu entry, right from the start, without first having to set it laboriously. They like the idea of a continuous glucose monitoring sensor that sits under the skin and measures their blood sugar levels. Some would even like to have those sensors connected with an insulin pump, so they would not need to calculate their insulin doses.

The first question of research has been answered by stating the importance of voice output and audio output in general. Also, haptics play a big role. There are many new developments in haptic research, where information and data is presented via ultra sound waves. Also, 2D and 3D visualization can be felt thanks to new technologies. Still, as with most industries, technologies have to become popular first in order to successfully integrate them into society, even if they would help numerous people with impairments long beforehand. For the second question of research the answer was that some of nowadays' blood glucose meters do have voice or audio output. The problem is that those functions often do not apply on all menu entries, therefore, just the current measurement is spoken by the device. Also, to assist with the menu navigation, the expert said that voice command could be helpful. The third question of research deals with the problems of common data distribution for visually impaired people. In this very visual world, especially when it comes to medical data, it is very important to include those how can't see. Applications like the Aipoly and Seeing AI do help in that matter and the four principles of barrier-free design help with understanding the need of disabled people and how those need can be transposed to reality. This is why the researcher is of the opinion that all medical devices should be accessible and give the option to choose between a barrier-free mode and standard mode as the first question when turning on the device.

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Appendix

A. Interviews

Interview Questionary

Stimmen Sie der Verarbeitung ihrer pseudonymisierten Daten im Rahmen dieser Master Thesis zu?

Name:
Alter:
Geschlecht:

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?

Sind beide Augen gleich betroffen?

Welchen Diabetes-Typ haben Sie und seit wann?

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?

Wie oft messen Sie Ihren Blutzucker?

Welches Blutzuckermessgerät verwenden Sie momentan?

Haben Sie auch schon andere Geräte verwendet?

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?

Inwiefern ist Ihr Gerät an Ihre Sehschwäche angepasst?

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?

Wie zufrieden sind Sie mit Ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.

Was könnte besser sein?

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)

Wodurch erfahren Sie, ob die von ihnen getätigte Eingabe erfolgt ist?

Kommen Fehlermeldungen vor? Wenn ja, wie oft?

Werden die Messwerte gespeichert? Wenn ja, wie viele?

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? Z.B. eine vertonte Kurve?

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?

Interview 1

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.
- Ich bin von Geburt an blind. Es war angeborenes Glaukom. War im Blindeninstitut in der Schule.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?
- Keine Sehleistung mehr vorhanden

Sind beide Augen gleich betroffen?
- Beide Augen gleich.

Welchen Diabetes-Typ haben Sie und seit wann?
- Typ 1 Diabetes seit 1984.

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?
- 7,6

Wie oft messen Sie Ihren Blutzucker?
- 3-4 mal am Tag

Welches Blutzuckermessgerät verwenden Sie momentan?
- Wellion mit Sprachausgabe (Wellion Calla Dialog)

Haben Sie auch schon andere Geräte verwendet?
- Gluki Plus, Firma Caretec und GlucoTalk, Firma Alere

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?
- ich habe mich mit meinem vorigen Gerät geärgert. Habe dann bei der Firma MedTrust angerufen. Dort gab es ein Angebot, das erste Gerät bekommt man gratis. Normal kostet eines 19,90€. Die sagten sie schicken mir gleich 3, 2 krieg ich gratis, das Dritte zahl ich selbst. So kann ich eines in der Arbeit und eines zu Hause lassen, das Dritte ist für unterwegs. Zwei habe ich bereits ausgetauscht, weil sie nicht mehr genau gemessen hatten.

Inwiefern ist Ihr gerät an Ihre Sehschwäche angepasst?
- Es hat eine Sprachausgabe

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?
- Wichtig ist das es spricht, ohne Sprachausgabe hilft es mir nichts. Das Zweitwichtigste ist, das es sagt, wenn die Batterien leer sind. Am wenigsten wichtig sind die Spracheinstellungen, also welche Stimmen und Sprache man auswählen kann.

Wie zufrieden sind Sie mit Ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.
- 4

Was könnte besser sein?
- Wenn ich einen Wert nachschauen möchte, muss man den im Speicher ablesen, doch das kann ein Blinder nicht. Ich habe das den Herstellern schon gesagt. Die Uhrzeit kann man auch nicht einstellen. Ich tippe die Werte manuell im Computer ein um auf alte Werte zuzugreifen.

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?
- Nein, da muss ich das Handy nehmen und auf Google nachschauen.

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)
- 3

Wodurch erfahren Sie, ob die von Ihnen getätigte Eingabe erfolgt ist?
- Die Menüpunkte werden vorgelesen und es piepst.

Kommen Fehlermeldungen vor? Wenn ja, wie oft?
- Ja, bei zu wenig Blut am Teststreifen meldet es Fehler. Das kommt bei kalten Händen vor oder wenn der Blutzucker sehr niedrig ist, im Winter häufiger.

Werden die Messwerte gespeichert? Wenn ja, wie viele?
- Ja, aber ich weiß nicht wie viele.

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?
- die werden leider nicht vorgelesen, ich muss sie mir über den PC anhören.

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? Z.B. eine vertonte Kurve?
- Sprachausgabe fände ich besser, aber die vertonte Kurve würde mir auch sehr gefallen.

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?
- Da habe ich keine Probleme.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?
- Was nicht schlecht wäre, wäre ein Chip der den Blutzucker misst und einem warnt wenn der Zucker zu niedrig ist oder einem die Insulinmenge ausrechnet. Oder einfach Tendenzen, ob der Blutzucker steigt oder sinkt.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
- Was man verbessern könnte wäre die Verbindung vom Freestyle Chip mit der Handy App. Es wäre schön sich nicht so oft stechen zu müssen. Man bräuchte nur eine App mit Sprachausgabe.

Interview 2

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.
- Durch mein Diabetes bin ich seit März 2003 erblindet. Der Sehnerv ist geschädigt.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?
- Keine Sehleistung mehr vorhanden.

Sind beide Augen gleich betroffen?
- Beide Augen sind gleich betroffen.

Welchen Diabetes-Typ haben Sie und seit wann?
- Typ 1 seit 2003.

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?
- ca. 8,9

Wie oft messen Sie Ihren Blutzucker?
- 4-5 mal am Tag.

Welches Blutzuckermessgerät verwenden Sie momentan?
- Wellion Calla Dialog

Haben Sie auch schon andere Geräte verwendet?
- Ja, ein normales, da brauchte ich Hilfe fürs Stechen. Und zwei andere sprechende Geräte.

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?
- Durch meine Ärzte. Ich habe schon gefragt, ob es für mich eines gäbe von den Geräten die man am Oberarm trägt, aber da gibt es noch keine Sprechende.

Inwiefern ist Ihr Gerät an Ihre Sehschwäche angepasst?
- Es spricht. Im Menü spricht es aber leider nicht.

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?
- Am wichtigsten ist das richtige Messen der Blutzuckerwerte. Am zweitwichtigsten ist die Sprachausgabe. Am wenigsten wichtig ist der Speicher, weil ich auf den nicht zugreifen kann, da dieser keine Sprachausgabe hat.

Wie zufrieden sind Sie mit ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.
- 4 bis 5

Was könnte besser sein?
- Dass auch der Speicher mit Sprachausgabe funktioniert.

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?
- Nein. Es gibt nur eine Bedienungsanleitung, aber die ist schriftlich.

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)
- 3

Wodurch erfahren Sie, ob die von Ihnen getätigte Eingabe erfolgt ist?
- Es piepst.

Kommen Fehlermeldungen vor? Wenn ja, wie oft?
- Bisher noch nicht.

Werden die Messwerte gespeichert? Wenn ja, wie viele?
- Ja, ich glaube ein paar hundert Werte.

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?
- Nein, sie werden nicht vorgelesen. Ich schreibe sie mir selbst auf oder lasse sie mir von Familie oder Freunden vorlesen.

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? Z.B. eine vertonte Kurve?
- Ja, das wäre sicher eine Hilfe.

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?
- Probleme habe ich da keine. Ich tue mir leicht beim Messen. Aber es kommt

manchmal vor, dass zu wenig Blut am Streifen ist.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?
- Es muss Sprechen können und auch alte Werte vorlesen mit Datum und Uhrzeit. Bequemer wäre es auch mit einem Sensor am Oberarm. So müsste man sich nicht mehr so oft Stechen und bekäme weniger Hornhaut am Finger.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
- Z.B. mit einem Sensor der dauernd den Blutzucker misst und die Werte mit Sprachausgabe vorliest.

Interview 3

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.
- Also, das kam vom Diabetes mellitus. Innerhalb eines halben Jahres sank die Sehleistung von 100% auf 10% und im weiteren viertel Jahr auf unter 2 % durch diabetische Retinopathie.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?
- Kann man nicht mehr in % ausdrücken, inzwischen wird nur mehr Hell-Dunkel-Sehen wahrgenommen.

Sind beide Augen gleich betroffen?
- Beide Augen sind fast gleich, das Rechte ist eher noch schlechter als das linke Auge.

Welchen Diabetes-Typ haben Sie und seit wann?
- Typ 2. Es wurde mit ca. 40 Jahren diagnostiziert.

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?
- 7,1

Wie oft messen Sie Ihren Blutzucker?
- Mindestens 4 mal pro Tag.

Welches Blutzuckermessgerät verwenden Sie momentan?
- Accu-Chek Mobile

Haben Sie auch schon andere Geräte verwendet?
- Accu-Chek Voicemate, OneTouch

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?
- Selbst recherchiert.

Inwiefern ist Ihr Gerät an Ihre Sehschwäche angepasst?
- Gar nicht, weil es hat keine Sprachausgabe hat, es piepst nur. Es piepst die

Werte in Hunderter-, Zehner- und Einerstellen.

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?
- Am Wichtigsten ist mir, dass ich keine Messstäbchen einführen muss, denn es hat eine Kassette. Am Zweitwichtigsten, dass es in irgendeiner Form eine Ausgabe hat, sei es durch Piepsen oder Sprachausgabe. Das Unwichtigste ist für mich Form, Größe, Art vom Gerät.

Wie zufrieden sind Sie mit Ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.
- 5

Was könnte besser sein?
- Wenn die Menüführung auch mit Sprachausgabe verfügbar wäre.

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?
- Nein

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)
- 2

Wodurch erfahren Sie, ob die von Ihnen getätigte Eingabe erfolgt ist?
- Durch ein Piepsen.

Kommen Fehlermeldungen vor? Wenn ja, wie oft?
- Ja, 1-2 mal im Monat.

Werden die Messwerte gespeichert? Wenn ja, wie viele?
- Ja, aber wie viele kann ich Ihnen nicht sagen.

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?
- Die werden vor gepiepst.

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? Z.B. eine vertonte Kurve?
- Nein, da habe ich keine Notwendigkeit dafür.

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?

- Sehr leicht mit der Kassette. Mit den Streifen kam ich gar nicht mehr zurecht und wusste nicht, ob die überhaupt richtig rum im Gerät waren.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?
- Ein CGM (Continuous Glucose Monitoring). Also ein Button den man direkt am Arm trägt für 1-2 Wochen, der misst dann automatisch den Blutzucker. Das wäre eigentlich das Idealste. Nur sind die heute noch fehleranfällig. Oder ein CGM kombiniert mit Insulinpumpe wo die Werte automatisch berechnet werden, das Insulin gepumpt wird und man nur noch kontrolliert, dass das Gerät keinen Blödsinn macht.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
- Indem man sprechende Geräte entwickelt die nicht nur den Messwert sprechen, sondern auch die Menüführung kommentieren. Und, dass es keine Teststreifen mehr gibt, sondern Kassetten oder andere Sensoren um Fehler zu vermeiden.

Interview 4

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.

- Durch Diabetes. Es fing mit Punkte im linken Auge an. Dann bin ich zum Augenarzt gegangen und der wusste auch nichts davon, bis ich einen Augenarzt in der nächsten größeren Stadt fand, der meinte es war vom Diabetes und schickte mich in eine Uniklinik. Das war 1970. Das Sehen wurde dann schlechter, das linke Auge war ziemlich schnell kaputt und mit Lichttherapie behandelt, Laser gab es damals noch nicht. Dann ging langsam das rechte Auge verloren und hatte nur mehr 10%. Links war keine Sehleistung mehr vorhanden. Dann hat man eine Hypophysenvorderlappenresektion gemacht und die Sehleistung stieg links wieder auf 60% an. Allerdings waren Einblutungen vorhanden und da man den Glaskörper nur mit Narbenbildung (als Nebenwirkung) entfernen kann, haben sich Narben gebildet und das führte zu einer Netzhautablösung. Im Laufe der Zeit ist dann auch der Sehnerv atrophiert.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?

- Keine Sehleistung

Sind beide Augen gleich betroffen?

- Ja

Welchen Diabetes-Typ haben Sie und seit wann?

- Typ 1 , seit 23. Lebensmonat, 1949

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?

- 6,1

Wie oft messen Sie Ihren Blutzucker?

- Gar nicht, ich hab ein Dauermesssystem, das Dexcom. Das misst kontinuierlich alle 5 Minuten den Zuckerwert im interstitiellen Wasser. Das sitzt am Bauch mit einem Sensor und sendet an ein Gerät. Und ich messe dann noch zum kalibrieren einmal am Morgen und einmal am Abend, alle 12 Stunden.

Welches Blutzuckermessgerät verwenden Sie momentan?
- Dexcom G4 dafür gibt es auch die App G5 mobile für das Smartphone. Die App ist auch für Blinde bedienbar, ich habe aber hat kein Smartphone.

Haben Sie auch schon andere Geräte verwendet?
-Eines von Roche mit Sprachausgabe. (Accu-Chek)

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?
- über Diabeticom weiterverbreitet.

Inwiefern ist Ihr Gerät an Ihre Sehschwäche angepasst?
- Es hat Alarme, wenn es einen Wert unterschreitet oder überschreitet. Aber das muss meine Frau ablesen. Ich könnte das nur mit der Smartphone App bedienen.

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?
- Am wichtigsten ist der Alarm für zu hohen Blutzucker, am zweitwichtigsten ist der Alarm wenn der Wert zu niedrig ist und am unwichtigsten ist die Anzeige, da ich die nicht lesen kann.

Wie zufrieden sind Sie mit Ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.
- 3

Was könnte besser sein?
- Sprachausgabe. Und der Sensor könnte kleiner sein, der ist 1,5 cm lang, 1cm breit und 1cm hoch.

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?
- Ja, einige. Aber ich erfahre nichts davon, das müsste meine Frau ablesen.

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)
- 1

Wodurch erfahren Sie, ob die von Ihnen getätigte Eingabe erfolgt ist?
- Gar nicht.

Kommen Fehlermeldungen vor? Wenn ja, wie oft?
- Nein, es kommen keine Fehlermeldungen vor. Nur wenn das Gerät keinen Empfang hat, zeigt es Sterne an. Das kommt ca. einmal im Monat vor.

Werden die Messwerte gespeichert? Wenn ja, wie viele?
- Es werden alle 5 Minuten ein Messwert gespeichert

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?
- Gar nicht. Sie interessieren mich auch nicht. Ich merkte mir die ungefähren Werte vom selben Tag.

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? z.B. eine vertonte Kurve?
- Ja, dann könnte ich sehen, in welche Richtung ich die Basalinsulindosis verändern muss, um noch bessere Werte zu erhalten.

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?
- Das macht alles meine Frau.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?
- Auf Sprachkommando meinen Blutzucker messen und mir dann mit Sprachausgabe mitteilen. Und auch für Taube per Schnittstelle z.B. in Braille ausgeben. Und genauer sein, nicht die +-15% Abweichung wie es im Gesetz steht, sondern nur +-2% Abweichung. Die Blutzuckermessgeräte sollten sich auch selbst Blut nach tanken, wenn sie nicht genug haben.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
- Durch Sprachausgaben und für Sehbehinderte große Displays. Am besten auf allen Geräten, denn jene die keine Sprachausgabe brauchen können sie ja abschalten.

Interview 5

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.
- Durch Diabetes ging meine Sehleistung vor ca. 14 Jahren im Alter von 43 Jahren verloren. Die diabetische Retinopathie verlief schleichend.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?
- Handbewegungen und Hell-Dunkel-Sehen auf einem Auge, das Andere ist vollblind.

Sind beide Augen gleich betroffen?
- Das linke Auge ist vollblind, das rechte nimmt Handbewegungen wahr.

Welchen Diabetes-Typ haben Sie und seit wann?
- Typ1, wurde vor 35 Jahren diagnostiziert.

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?
- 7,8

Wie oft messen Sie Ihren Blutzucker?
- 5-7 mal täglich.

Welches Blutzuckermessgerät verwenden Sie momentan?
- Freestyle Libre Link

Haben Sie auch schon andere Geräte verwendet?
-Ich hatte zuvor kein sprechendes Gerät, denn ich konnte die Zahlen am Display gerade noch erkennen. Das Gerät hieß Contour.

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?
- Ich hatte einen Bericht gelesen, dass das Freestyle Libre eine App auch für IOS Geräte hat mit der die Werte angesagt werden.

Inwiefern ist Ihr gerät an Ihre Sehschwäche angepasst?
- Das Gerät selbst kann man als blinder Mensch nicht nutzen, mit der App und

einem Smartphone geht es aber schon, durch Sprachausgabe.

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?
- Am wichtigsten ist die Sprachausgabe, am zweitwichtigsten ist die Programmierung/Einstellung. Dass es sich vielleicht selbst einstellt oder von mir leicht einstellbar ist, z.B. Uhrzeiten etc. Am wenigsten wichtig ist das Aussehen.

Wie zufrieden sind Sie mit Ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.
- 4

Was könnte besser sein?
- Könnte ich im Moment nicht sagen, ich habe es noch nicht so lange.

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?
- Ja, es gibt eine Trendkurve, die mir angesagt wird über die App. Also wenn der Blutzucker steigt, gleich bleibt oder sinkt, dann wird mit das über die App angesagt. Das kannte ich von anderen Geräten noch nicht.

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)
- 5

Wodurch erfahren Sie, ob die von Ihnen getätigte Eingabe erfolgt ist?
- Über Voiceover wird das angesagt. Es sagt „ausgewählt“, aber nur über die App.

Kommen Fehlermeldungen vor? Wenn ja, wie oft?
- Kam noch nicht vor.

Werden die Messwerte gespeichert? Wenn ja, wie viele?
- Alle Messwerte werden gespeichert.

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?
- Indem ich durch das Menü klicke und mir das über die App per Sprachausgabe ausgeben lasse.

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? Z.B. eine vertonte Kurve?

- Ja, eine vertone Kurve wäre nicht schlecht, momentan wird das nur als Diagramm dargestellt.

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?
- Sehr leicht, weil man keinen Bluttropfen am Streifen geben werden muss. Das Anbringen vom Sensor ist etwas problematisch. Ich kann mir auch vorstellen, dass es für ältere Personen noch problematischer ist. Das ist schon noch einfacher, wenn man eine sehende Person zur Hilfe hat.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?
- Es müsste barrierefrei sein, eigentlich müssten alle Geräte barrierefrei sein nach der EU Behindertenrechtskonvention. Und alle sollten sofort einsatzbereit sein, wenn ich das Gerät auspacke, sollte das sofort verwendbar sein für behinderte Personen. Wenn ein nicht behinderter Mensch das Gerät verwenden will, kann er sich das abschalten. Es darf aber nicht sein, dass ich ein Gerät erst mühselig dahin bringen muss, dass es mit mir spricht. Ich könnte mir auch vorstellen, dass man etwas unter die Haut pflanzt, das noch länger sitzt, damit nicht alle 14 Tage gewechselt werden muss. Dann geh ich mit dem Messgerät über diese Stelle, wie bei Hunden mit dem implantierten Chip. Das müsste aber auch barrierefrei sein.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
- Es sollten mehr Teststreifen freie Geräte gefördert werden. Haut freundlichere Pflaster wären auch gut. Und die Geräte sollten kostengünstiger werden da das Libre z.B. schon noch etwas teurer ist als andere Geräte mit Blutzuckerteststreifen.

Interview 6

Wodurch kam es zu Ihrer Seheinschränkung? Erzählen Sie von Ihrem Krankheitsverlauf hinsichtlich Ihrer Augen.
- Ich bin durch Diabetes erblindet. Bin mit 6 Jahren diagnostiziert worden und war dann mit 25 Jahren blind.

Wie viel Sehleistung besitzen Sie noch in %, bzw. können sie noch Handbewegungen erkennen oder zwischen Hell-Dunkel-Sehen unterscheiden?
- Gar nicht mehr, 0% würde ich sagen.

Sind beide Augen gleich betroffen?
- Beide Augen gleich.

Welchen Diabetes-Typ haben Sie und seit wann?
- Typ 1 seit dem 6. Lebensjahr

Kennen Sie Ihren letzten Langzeitzuckerwert, den HbA1c?
- 8,5

Wie oft messen Sie Ihren Blutzucker?
- Kontinuierlich

Welches Blutzuckermessgerät verwenden Sie momentan?
- Freestyle mit iPhone App.

Haben Sie auch schon andere Geräte verwendet?
- GlucoTalk, Gluki Plus, OneTouch

Wie kamen Sie zu dem momentanen Gerät? Wurde es Ihnen empfohlen oder haben Sie es selbst recherchiert?
- Das wurde mir von einer Freundin empfohlen.

Inwiefern ist Ihr Gerät an Ihre Sehschwäche angepasst?
-Eigentlich gar nicht, das eigentliche Ablesegerät funktioniert für Blinde gar nicht. Und da habe ich dann eine Schlichtung mit Abbott beantragt, weil ich das ungerecht gefunden habe, dass es endlich eine tolle Lösung gibt für Blinde, die sich sowieso schon schwer tun den Blutstropfen auf den

Teststreifen zu bringen, und dann ist das aber nicht zugänglich. Dann gab es die Handy-App und wurde so zugänglich für blinde Menschen.

Welche Funktion Ihres Gerätes ist Ihnen am wichtigsten, welche am zweitwichtigsten und welche Funktion ist am wenigsten wichtig?
- Es ist besonders toll den Blutzucker ohne stechen messen zu können. Außerdem ist es jeder Zeit abrufbar und so oft messbar wie man möchte, ohne sich um Teststreifen kümmern zu müssen. Etwas Unwichtiges gibt es nicht.

Wie zufrieden sind Sie mit Ihrem Gerät auf einer Skala von 1-5? 1 bedeutet sehr unzufrieden und 5 sehr zufrieden.
- 5

Was könnte besser sein?
- Dass es leichter ist die anderen Daten abzulesen, dass ich (im Menü) besser hinkomme.

Bietet Ihr Gerät situationsspezifische Erklärungen oder Hilfestellungen, die konkret weiterhelfen?
- Nein, es sagt nur den aktuellen Wert und steigende oder fallende Trends.

Wie leicht fällt es Ihnen durch das Menü des Gerätes zu navigieren? (Skala 1-5 sehr schwer bis sehr leicht)
- 1

Wodurch erfahren Sie, ob die von ihnen getätigte Eingabe erfolgt ist?
- Bei der App mit Sprachausgabe und piepsen.

Kommen Fehlermeldungen vor? Wenn ja, wie oft?
- Nein, mit dem iPhone nicht. Das Freestyle Ablesegerät meldet aber manchmal Sensorfehler. Da musste man dann 10 Minuten warten um erneut messen zu können.

Werden die Messwerte gespeichert? Wenn ja, wie viele?
- Ja, alle innerhalb von 8 Stunden.

Wie erfahren Sie von älteren Messwerten? Werden diese vorgelesen?
- Soweit kam ich noch nicht, das muss ich erst herausfinden, wie man das macht mit dem iPhone.

Würde Ihnen ein Überblicks-verlauf der Messwerte gefallen? Z.B. eine vertonte Kurve?

- Ich würde eher die Werte abrufen wollen.

Wie leicht tun Sie sich mit der Handhabung des Geräts? (Nadel wechseln, Finger stechen, Messstreifen einlegen) Wo liegen eventuelle Probleme?
- Den Sensor zu injizieren schaffe ich nicht allein. Ich kann ihn zwar setzen, aber ich brauche jemanden der ihn dann für mich injiziert.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste ein für Sie perfektes Blutzuckermessgerät alles können?
- Ein Kombigerät, das den Blutzucker misst und dann gleich die richtige Dosis Insulin abgibt.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
- Die Idee von der Apple-watch, die die Werte über den Wiederstand der Haut misst find ich toll. Man braucht keine Angst zu haben sich den Sensor runter zu reißen oder hängen zu bleiben und muss sich nicht mehr stechen. Das wurde schon einmal angekündigt, aber jetzt hört man nichts mehr davon.

Expert Interview

Wodurch erfahren Kunden mit Sehbehinderungen von Ihren Produkten oder Blutzuckermessgeräten generell?
- Prinzipiell vom Hausarzt, vom behandelnden Facharzt bzw. vom Diabetesteam. Natürlich auch aus der Werbung – wir machen beispielsweise auch Radiowerbung für unsere Produkte.
Meine eigene Mutter ist schwer sehbehindert und daher weiß ich, dass auch die Vereine (wie beispielsweise der Blindenverband) Hilfe und Unterstützung anbieten.

Welche Rolle spielen die Sozialversicherungsträger im Zusammenhang mit dem Vertrieb/der Verbreitung von Blutzuckermessgeräten?
- Mit Vertrieb und Verbreitung direkt gar keine. Es hat früher Bestrebungen einzelner Versicherungsträger gegeben die verschreibenden Ärzte dahingehend zu beeinflussen, dass Geräte verschrieben werden, die besonders günstig für die Krankenkasse sind – ohne Bewertung von Qualität. Das gibt es aber heute nicht mehr. Es ist wichtig, dass auch neuere Methoden und Geräte von der Kasse vergütet werden, damit jeder mit dem versorgt wird was er/sie benötigt.

Inwiefern sind Blutzuckermessgeräte heutzutage an Sehbehinderung und Blindheit angepasst?
- Die neuen Technologien haben auch in diesem Bereich Einzug gehalten. Es gibt schon lange ein sprechendes Blutzuckermessgerät. Doch auch mit Apps in Kombination mit Messtechnologien gibt es eine Reihe von Hilfestellungen.

Welche Funktionen der Geräte sind für seheingeschränkte Personen Ihrer Meinung nach am wichtigsten, welche am zweitwichtigsten und welche Funktionen sind am wenigsten wichtig?
- 1.Messergebnis lesbar/hörbar. 2.Handling mit Teststreifen, Blutauftrag usw. auch für Sehbehinderte möglich. Am wenigsten wichtig: Spezielle bunte Cover, Taschen, Aufkleber

Was könnte an Blutzuckermessgeräten heutzutage noch besser sein?
- Generell ist die Qualität heutzutage extrem gut - von fast allen Anbietern.
Die Geräte sind auch in allen Formen, Farben, Funktionalitäten, Größen usw. erhältlich. Da diese Fragen auf Sehbehinderte abzielen kann in diesem Bereich sicher noch etwas verbessert werden und zusätzliche Funktionen wie Sprachsteuerung im Menü usw. entwickelt werden.

Gibt es Möglichkeiten die Menüführung für seheingeschränkte Personen noch einfacher zu gestalten, wenn ja wie?
- Siehe Frage oben – Sprachsteuerung zum Beispiel.
Minimale Menüführung am Gerät nötig (Ersteinstellung, dann keine Aktion nötig). Auswertungen und Speicher auf einem PC, Tablet, ….

Was könnten mögliche Fehlerquellen beim Messen des Blutzuckers sein?
- Bei Sehbehinderten? Nicht anders als bei anderen Diabetikern: Hände nicht sauber, zu wenig Blut aufgetragen, zu viel gequetscht und daher verfälschtes Ergebnis,…

Einige Blutzuckermessgeräte haben Sprachausgaben mit der seheingeschränkte Personen ihre Werte vorgesprochen bekommen. Doch darüber hinaus funktioniert die Sprachausgabe dann nicht mehr. (Menü, Speicher, etc. wird nicht mehr vorgelesen) Gibt es einen Grund dafür, dass die Sprachausgabe nur für die Ausgabe des aktuellen Messwertes funktioniert?
- Das kann ich nicht beantworten, da wir kein Blutzuckermessgerät mit Sprachausgabe haben.

Kennen Sie Möglichkeiten/Technologien um Überblicksverläufe und Kurvendiagramme der Messwerte auch für seheingeschränkte Personen zugänglich zu machen?
- Wie schon erwähnt ist meine Mutter auch schwer seheingeschränkt. Trotzdem gibt es unzählige Hilfsmittel wie extreme Lupenbrillen, - Vergrößerungsprogramme für den PC, Bildschirmlesegeräte und sonstige Lesehilfen. Diese Produkte sind allerdings sehr teuer und sollten mehr von den Sozialversicherungsträgern unterstützt werden.

Warum beinhalten nicht alle Blutzuckermessgeräte von Anfang an die Option der Sprachausgabe, welche von jenen die sie nicht benötigen einfach abgestellt werden kann?
- Jedes technische Detail kostet in der Entwicklung Geld und ist danach eine mögliche Fehlerquelle mehr. Der Trend geht eher hin zu „möglichst einfach“ und weniger zu alle Funktionen anbieten und dann den Anwendern erklären wie sie diese wieder ausschalten können.

Sind Sie persönlich der Meinung, dass alle Medizinprodukte, welche vom Anwender/Patienten selbst bedient werden, barrierefrei sein sollten?
- Nein, ich bin der Meinung, dass es barrierefreie Medizinprodukte in jedem Bereich geben sollte, aber nicht jedes Medizinprodukt muss barrierefrei sein. Ein Sportler bekommt ein für den Sport ideales Medizinprodukt, ein Sehbehinderter bekommt ein Medizinprodukt speziell für diese Bedürfnisse.

Gib es Möglichkeiten seheingeschränkten Personen die Handhabung des Geräts zu erleichtern? (Nadel wechseln, Finger stechen, Messstreifen einlegen, Sensor anbringen/injizieren, etc.)
- Die Handhabung muss einfach wegfallen oder so minimal oder selten werden, dass es kein Problem mehr ist.

Stellen Sie sich eine Zukunft vor in der technisch alles möglich ist, was müsste DAS perfekte Blutzuckermessgerät alles können?
- In der Zukunft gibt es keine Blutzuckermessgeräte mehr. Kein Fingerstechen, kein Blut auftragen usw. Die Technologie macht ja gerade einen Sprung nach vorne. Alle, auch Sehbehinderte werden es einfacher haben ihren Diabetes zu managen.

Haben Sie noch letzte Anmerkungen/Wünsche/Ideen wie man das Blutzuckermessen für seheingeschränkte Personen verbessern könnte?
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