GUM: A SMART SYSTEM FOR SENIORS WITH DIABETES

by

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ABSTRACT

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Diabetes is a prevalent disease nowadays, and it is a big challenge, especially for seniors. The biggest challenge for seniors with diabetes is that they need to prick their fingers to test their blood which is painful and horrible. Also, the current glucose meter does not make good use of the glucose data to help them better treat the diabetes. Also, seniors live alone and lag off behind the diabetes information & technology. Therefore, based on seniors' characteristics, I want to employ new technologies, such as data visualization and AI technology, in the design to help them manage their diabetes more easily.

Through the literature review, I learned the disease information of diabetes, investigated the diabetes situation in the seniors' group, and studied the seniors' characteristics, which can make the designs more suitable for seniors. To better understand diabetic seniors' conditions, needs and wishes, I took part in several diabetes events in Lafayette Indiana, volunteered in the retirement village and conducted a series of interviews in these two settings. By analyzing the peer products, daily self-measurement of my own sugar level and keeping diaries, I learned what do the similar products look like, got some inspiration from them and found problems in the current products. After drawing a bunch of sketches to explore the idea, HTA chart, wireframe, low-fidelity prototype and mockups were developed in the first design iteration. I came up with the smart product system, based on the seniors' characteristics, combined with new technologies to help seniors with diabetes easily manage their diabetes. Then I conducted the usability testing with the prototype & physical models to refine my design. Finally, usability testing was conducted again to make sure my products provide a pleasant experience for seniors with diabetes. With this smart system, testing blood becomes a happy & relaxing experience and seniors can join the diabetes group to support each other. Moreover, Seniors with diabetes can get feedback and suggestions from the system.

Keywords: seniors with diabetes, data visualization, AI technology, user experience.

INTRODUCTION

The prevalence of diabetes in the United States has increased very quickly in recent years. Diabetes is most severe among the senior group in the US: Twelve million seniors were reported to have diabetes in 2015, accounting for twenty-five of people with diabetes (ADA, 2018). More than forty percent of people with diabetes are seniors (ADA, 2018). As the baby boomers are getting old, the number of seniors with diabetes will continue to increase rapidly in the near future. In comparison to young adults, the elderly with diabetes have a greater risk of complications such as stroke, heart diseases, cognitive impairment, impaired physical functioning, all of which will make their diabetes management even harder.

More and more seniors are tending to use technology since they perceive that benefits of using smartphones outweigh their costs (Fisk et al., 2018). Once they learned how to use technology, they will find it is really helpful in improving their life quality. The number of seniors owning smartphones has grown very quickly in recent years and has doubled in the past five years in the U.S. Nowadays almost fifty percent of seniors, aged 65 and up, own smartphones in the U.S., and the number is expected to arrive at sixty-seven percent in 2020 (PRC, 2018). However, most high-tech products are designed for the general public, and seniors can feel very frustrated when using them since they have their own characteristics. As seniors grow older, they will have more limitations on perception, cognition, and movement controls (Fisk et al., 2018), such as much more haptic control variability, high vibration perception thresholds, hearing losses, visual impairment, memory loss, attention deficit, spatial cognition decline, difficulty in understanding written language and worse movement controls.

Diabetes is a very common disease nowadays, and it is a big challenge, especially for seniors. Many problems have been found during research: (1) There is a need for more supporting information. (2) Testing the blood glucose level is not comfortable. (3) Seniors with diabetes feel awkward to test the blood in public. (4) Seniors with diabetes forget to test the blood sometimes. (5) Data can be used to treat diabetes better. (6) Seniors have a hard time figuring out different medicine. (7) Their vision problems can be an obstacle. (8) It is inconvenient for seniors to visit doctors. (9) Some seniors have no medicine adherence. (10) Seniors dare not eat anything. (11)

Seniors with diabetes cannot do exercises when they have ankle cracks. (12) It is hard for them to change their habits. (13) The cost is a lot. In this project I focused on solving three problems: seniors always live alone and are lag off the new information & technology because of their cognitive and physical impairment; Seniors with diabetes need to prick the finger to test their sugar level for six times which is painful; The diabetes products are still not so smart in the market. For example, we can make good use of data to help them treat the disease better.

Based on seniors' characteristics, this project used new technologies to build a smart system for seniors with diabetes. With this smart system, testing blood becomes a happy, relaxed and elegant experience without any hurt. The system can offer seniors with feedbacks and suggestions according to their data. Moreover, seniors can join the diabetes group around them to support each other and ask the diabetes expert questions.

LITERATURE REVIEW

Elderly Diabetes Conditions

Diabetes

Diabetes develops when the blood sugar or the blood glucose in our blood is too high. Blood glucose coming from our food is the main source of energy for the human's body, and insulin will transform it into our cells. However, some people's body cannot produce insulin, which means the glucose from the food cannot enter the cells. Therefore, glucose will stay in their blood and leads to diabetes.

Diabetes prevalence has increased very quickly in recent years in the United States. In 2015, 30.3 million people, accounting for almost ten percent of the whole population of the United States, were reported to have diabetes. The situation is even worse among seniors: nearly one in four seniors over the age of sixty-five has diabetes (CDCP, 2017). If people have a family history of diabetes or are overweight, they are more likely to get diabetes. Moreover, people with prediabetes or gestational diabetes are easier to get the other disease. Some factors such as physical inactivity and high blood pressure can also make it easier for people to get the disease.

Age	Percentage (95%CI)		
Total	9.3 (8.5–10.1)	2.9 (2.4–3.5)	12.2 (11.3–13.2)
18–44	2.6 (2.2–3.1)	1.3 (0.9–2.0)	4.0 (3.3–4.8)
45–64	12.7 (11.1–14.5)	4.3 (3.3–5.5)	17.0 (15.1–19.1)
≥65	20.8 (18.8–23.0)	4.4 (3.1–6.3)	25.2 (22.5–28.1)

CI = confidence interval

Figure 1 Estimated Percentage of Diabetes among Adults in the United States, 2015

If people do not make an effort to control their diabetes, they will have a high risk of having other health problems, such as heart diseases, stroke, kidney diseases, eye problems, dental

diseases, nerve damage and foot problems. Essential ways to treat diabetes complications are keeping the blood sugar levels under control, exercising, losing weight, and living a healthy life.

Elderly Diabetes

The United States is now experiencing the aging of population: There will be three and a half young adults for every retirement-age person by 2020, and the ratio will increase to two and a half by 2060 (U.S. Census Bureau, 2018). The median age of the U.S. population is now 38 and will be 43 in 2060. As the baby boomers are growing old, the size of the older population will increase. It is estimated that one in five people will be seniors by 2030, which will be the first time in U.S. history that the seniors outnumber children (U.S. Census Bureau, 2018). Due to the aging population, the diabetes prevalence is estimated to be doubled in the next twenty years. Other projections suggest that between 2005 and 2050, the number of seniors with diabetes, aged 65 or older, will increase by 4.5-fold (Narayan, Boyle, Geiss, Saaddine, & Thompson, 2006). The quickly increasing aging population will bring about lots of challenges since there will be higher demands for hospital services. However, the number of hospitals and doctors has not grown accordingly, which means there is an unbalance between seniors with diabetes and the extent of hospital services. Therefore, seniors have to wait for a long time for an appointment to see doctors.

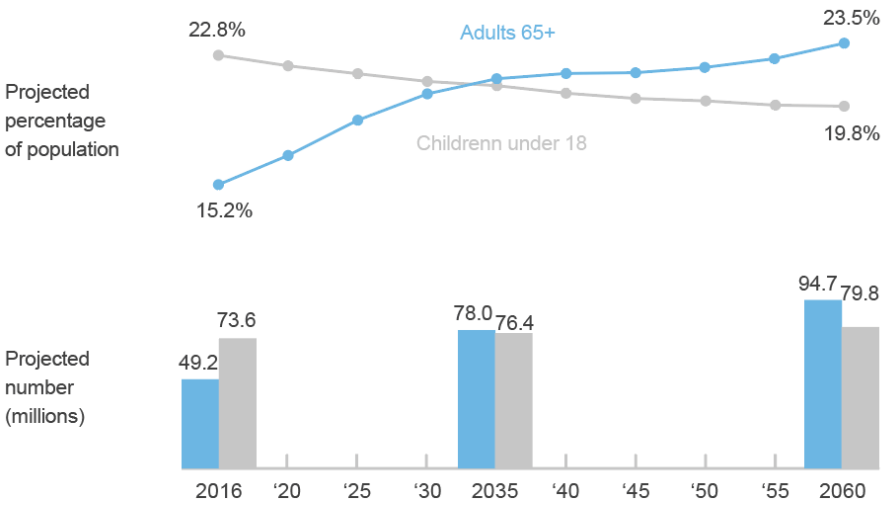


Figure 2 Projected Number of Children and Older Adults

The reason why it is comparatively easier for seniors than young adults to get diabetes is the increased insulin resistance and damaged islet function. Seniors with diabetes have a higher

mortality rate, high hospitalization frequency, and lower function status. It is also easier for them to get microvascular and cardiovascular complications (Kirkman et al., 2012).

Elderly Diabetes Measures

Screening for diabetes and prediabetes, glycemic control, medication, and a healthy lifestyle are the measures every person with diabetes needs to take. In the next section, I will discuss what seniors need to consider specifically related to these measures.

Screening for Diabetes and Prediabetes

Seniors have a very high risk of getting diabetes. The American Diabetes Association (ADA) suggested that seniors should be screened for diabetes every one to three years. Screening and identifying diabetes benefits will depend on whether the primary and secondary interventions will be useful on the expected timeframe versus their life expectancy (Kirkman et al., 2012). It is better for seniors aged 65 to do diabetes screening since they can get a lot of benefits considering that they still have decades of remaining life. However, for those over 95, most people would agree that it is unnecessary to do diabetes screening.

Glycemic Control

Seniors who are healthy and have a high life expectancy can use the sugar level control targets similar to those of young people. Seniors with functional impairment, cognitive dysfunction, and a short life expectancy can use a more relaxed target. However, they should avoid hyperglycemia leading to symptoms and hyperglycemic complications.

A Good Lifestyle and Medications.

Diabetes can be prevented and delayed by a healthy lifestyle and the medications, which will have more effects on seniors than young adults. According to a study conducted by the Diabetes Prevention Program, lifestyle intervention can be more beneficial to seniors than young people: there will be forty-nine percent risk reduction in seniors compared with a thirty-four percent reduction in the total population (Kirkman et al., 2012). A good lifestyle can also have other benefits like urinary incontinence reduction, improving cardiovascular disease and so on.

Elderly Diabetes Considerations

Except for the measures mentioned before, more issues such as cognitive and functional impairment, polypharmacy, depression, nutrition, and diabetes education need to be considered, especially in the case of seniors. Diabetes is a complicated and hard enemy, and the support of the other members of the patient's community, such as family members, friends and caregivers, is also needed.

Cognitive Impairment

Dementia is twice as likely to happen in people with diabetes than healthy people (Lu et al., 2009). Cognitive impairment includes dementia, Alzheimer's disease, and memory loss, and it will make it difficult for patients to complete tasks such as glucose measurement, medicine changing, and keeping a healthy diet. Seniors with diabetes need to screen for cognitive problems periodically. For seniors with diabetes, we need to simplify their treatment regiments, involve the caregivers, and assess the hypoglycemia occurrence (Kirkman et al., 2012).

Functional Status

Both aging and diabetes will affect the functional status. If we control the age, people with diabetes are more likely to get functional impairment than general public (Gregg et al., 2002). The reasons for the functional problems include peripheral neuropathy, visual impairment, hearing difficulty, gait and balance problems. Peripheral neuropathy appears in fifty to seventy percent of seniors with diabetes, increasing the possibilities of getting balance problems and muscle atrophy, which will affect their exercises and make them easier to fall (Kirkman et al., 2012).

Polypharmacy

Seniors with diabetes are more likely taking several medications, which will increase their risk of problematic interactions and drug side effects. In addition, using multiple medications will increase their financial burden. Therefore, they need to access the medical indications, medicine adherence and barriers when they visit their doctors (Kirkman et al., 2012).

Depression

Seniors with diabetes have a high rate of depression which will cause a lot of problems, such as difficulty in self-care and making healthy choices, increased mortality rates and increased risk of dementia. Seniors need to screen for depression periodically with tools such as the Geriatric Depression Scale (Montorio & Izal, 1996).

Nutrition issues

Because of strict diabetes control, anorexia, swallowing problems, dental issues, and functional impairments which will make preparing food difficultly, seniors with diabetes are more likely to suffer from malnutrition. There are some ways to improve the nutrition, such as small frequent meals, food texture changes, and addition of liquid nutrients between meals (Kirkman et al., 2012).

Diabetes Self-management education

Seniors are not so skilled at technology, so they cannot easily get access to diabetes resources like the latest diabetes medicines or technology. Therefore, diabetes self-management education is needed to help them know how to treat the disease with a better approach. Diabetes self-management education needs to consider seniors' characteristics like vision and hearing impairments, cognition, and functional status. Family members, friends and caregivers need to join in to support seniors. When communicating with seniors, educators need to address the seniors by name and try to use simple terms and signals. When introducing the tasks, educators should introduce them from the simplest to the most complex.

Almost twenty-five percent of seniors have the diabetes in the US and it is the highest ratio among the whole population. In addition, seniors account for forty percent of the whole population. So seniors with diabetes is a huge population. Seniors with diabetes have their special situations, such as cognitive and functional impairment, polypharmacy, and so on, which means the diabetes treatment ways are different from young adults. Therefore, for diabetes products, we need to consider the special conditions and needs of seniors. Otherwise, the seniors cannot easily get access to these products, and companies will lose a big market.

Elderly Characteristics

The elderly will have some sensory impairments when they are getting older, which is inevitable and limits their quality of life. These sensory impairments can reduce their capability of communicating with others, moving from one place to the other places, and performing their daily activities, which will cause the isolation, depression and poorer social relationships.

In the sensation part, I will introduce briefly the issues that come with the elderly taste & smell, vision, haptics, and audition impairments. In my opinion, the vision and audition are most pertinent among these because they are about the capabilities and limitations of users, and are closely related to the design.

Elderly Sensation: Taste and Smell

As seniors grow older and older, their taste and smell ability will decrease which will make it harder for them to distinguish among various foods and odors. People's ability to perceive the sweet, sour, bitter and salty will not change before the age of sixty. After the age of sixty, individuals will have higher thresholds for different tastes, as if they have a cold experience during which they will feel that everything is tasteless (Montorio & Izal, 1996).

When seniors arrive at seventy years old, their olfactory will decline because of the nerve ending loss. They will not only lose their sense of smell but also cannot distinguish among different smells. Therefore, when we design the products for this age group, we need to consider their detection thresholds of seniors.

Elderly Sensation: Vision

Almost twenty percent of seniors seventy years old and older have vision problems, including blindness. The risk of having such problems is increased with aging. Seniors with the vision loss are more likely to fall which will make them easier to go to the hospital or the nursing home. For the elderly, vision impairment can make it harder for them difficult to read the small print on the pills and distinguish among the different medications. Consequently, medication misuse might occur more often.

Elderly Sensation: Haptics

Haptics relates to the sense of touching. As people grow older, their haptic control will become more variable, and temperature & vibration perception thresholds will also increase, which will make their touch and perception inaccurate (Fisk et al., 2018). Seniors lack the sharp sense of hot and cold objects, skin damage and pain. Therefore, senior products should avoid sharp edge angles and have the obvious convex-concave distinction.

Elderly Sensation: Audition

As people grow older, their hearing ability will decline due to receptor hair cells' and neurons' deterioration and inner ear vascular changes (Fisk et al., 2018). About half of men and thirty percent of women suffer hearing loss. Young people can hear 15,000 vibrations per second for tones in frequencies. When individuals are over the age of sixty-five, they can only hear up to 4000 vibrations per second. Therefore, when we design products for them, we need to be aware that hearing loss of seniors may affect their interaction with the devices.

Elderly Cognition: Memory

When people interact with the products, the cognitive components will also be involved. As designers we need to consider the senior cognition changes to help them achieve successful performance. The following figure shows the definitions of cognitive constructs (see Figure 3).

Working memory	Active memory of what has just been perceived and what is currently being thought about. It consists of new information and information that has recently been retrieved from long-term memory. Only a few bits of information can be active in working memory at any one time (think of holding three names in memory versus ten names). Information held in working memory decays quite rapidly unless it is rehearsed to keep it there.
Semantic memory	Long-term memory for acquired knowledge; includes such concepts as vocabulary words, historical facts, cultural norms, rules of language, art and music information, and more.
Prospective memory	Remembering to perform an action in the future. Time-based prospective memory tasks are those in which the person must remember to do something at a certain time (e.g., at 2:00 p.m.) or after a particular amount of time has passed (e.g., in 2 hours). Event-based prospective memory tasks are those in which something must be done in response to an event (e.g., when the buzzer goes off, turn off the oven).
Procedural memory	Procedural memory is knowledge about how to perform activities. Procedural memory varies along the dimension of automaticity, from knowledge that is executed almost without thought (e.g., shifting gears or steering a car) to explicit but well-practiced routines (e.g., following a recipe).
Attention	The process that controls awareness of events in the environment; attention determines the events to which we become conscious. Attention is limited — it operates selectively on stimuli in the environment. A person in the midst of multiple conversations can only "pay attention" to one particular conversation. Attention capture is a response to salient cues (e.g., if someone calls your name). Attention can be divided across sources of information or switched between tasks.
Spatial cognition	The ability to manipulate images or patterns mentally; the ability to represent information and transform it (e.g., mentally rotate an image) or to accurately represent spatial relationships among components.
Language comprehension	The ability to interpret verbal information, whether written or spoken. Includes the ability to understand individual words, to understand sentences and paragraphs, and to draw logical inferences that are implied in a text or discourse.

Figure 3 Definitions of Cognitive Constructs (Fisk et al., 2018, p.19)

People in their 60s and 70s have greater difficulty remembering names and finding words than they did in their teens and 20s. They could also have an increasing tendency for everyday forgetfulness. They forget where they left their glasses or a book, or they fail to carry out a task that they had decided to do only minutes ago. Seniors who have Dementia always forget to take

the medicine or even can't remember if they had taken the medicine or not which may cause serious problems especially for those who have heart disease, diabetes, high blood pressure and more.

Elderly Cognition: Attention

Our limited ability for information processing is called attention (Proctor, 2008). When we interact with the products, we sometimes need to search, which will need our selective attention. For example, we need selective attention to find the color system button under the google design resources website. When the attention demands increase, seniors will have more performance problems.

Dynamic visual attention refers to people's reoriented attention from one item to the other item in a certain environment (Fisk et al., 2018). It will take seniors more time than young people to move their attention from one place to another.

Seniors' attention is more likely to be captured by prominent objects, such as flashing lights, than young adults. When we design products for seniors, they should not be asked to search a lot in order to be able to perform the task. Try to make the design simple and leave out the useless information which will distract seniors' attention. It is also important to let seniors perform simple tasks since they are slower to complete the complex tasks.

Elderly Cognition: Written Understanding

If the connections between two ideas are not obvious, it will need some inferences to help understand, which is more difficult for seniors with the working memory limitations. Their comprehension will improve if the tasks rely on their semantic memory. Therefore, when we design the system, we need to use simple terms and some icons, graphs and pictures to help them understand.

When we design products for seniors, we need to know the sensation, perception, cognition, and the mood of seniors and understand these will decline with age. We need to use the design ways to make up for these declines and limitations.

Seniors with Technologies

We are now entering the digital age, and technology has entered every corner of our lives at an unprecedented pace. More and more seniors are overcoming the barriers and embracing technologies such as smartphones, laptops, tablets, e-reader and more. They are tending to find that technology has brought them a lot of new possibilities and makes their lives much accessible and independent.

Technology Adoption Among Seniors

Although still less than young people, seniors' use of technology is growing. The most popular technology among seniors are smartphones, the internet, GPS, and tablets (see Figure 4). According to the Pew Research Center, over half of seniors use more than one technology for work or contacting their friends and family members by 2014. They always surf the internet to get information about world events, sports, and other entertainments. Although some seniors still hesitate to use the internet, they will be very active once they used that; Seniors find it is very convenient to use GPS than using the paper maps. They especially like systems with large screens which are more comfortable for them to read; Almost forty percent seniors own the tablets, and they think that tablets bring them much more convenience since they can access thousands of books from this device, and they can magnify a book's text. (see Figure 4).

Technology	Condition
Internet	By 2014, over half of all baby boomers were using more than one piece of technology, such as a cell phone, tablet and/or computer.
Gps	Boomers have shown they like to use GPS Especially like the larger screens
Kindles and e-readers	About one in five seniors owns an e-reader Owners like the ease and convenience they offer
Smarphones	More than half of Americans over 50 own a smartphone

Figure 4 Technology Adoption among Seniors

Among all the technologies, smartphones are the most popular (see Figure 5). According to the American Association of Retired Persons (AARP), almost sixty-five percent of seniors own smartphones. Smartphones can conveniently make them get connected by voice, text, and email.

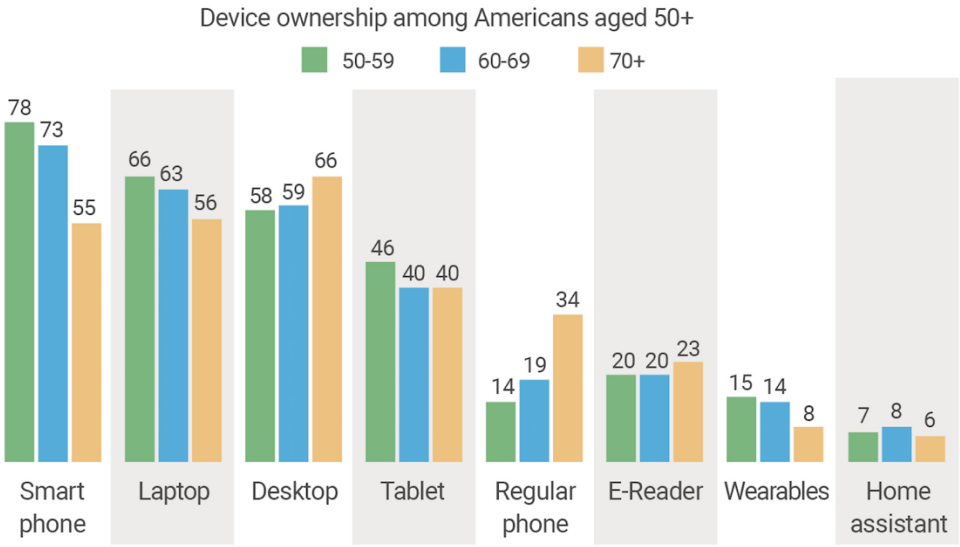


Figure 5 Device Ownership among Americans Aged 50+ (AARP, 2017)

There are many benefits for seniors to use modern technologies:

1. Technology allows them to keep in touch with the family members who live far away and who are so busy that they cannot visit them in person.
2. It encourages them to talk with other people so they will not feel isolated or depressed.
3. It helps them catch up with the latest news and technology about the topics they are interested in.
4. It helps them get access to entertainment online to make their lives more interesting.

A study from UCLA shows that surfing the internet online can improve seniors' cognitive function. The internet can also assist in depression and anxiety treatment.

Barriers to adoption technology

Some obstacles hinder them from using modern technologies. These can be physical, such as physical or health status. Sometimes psychological problems may occur. For instance, they may feel anxious when they use the new technology.

(1) Physical barriers. Some seniors have health problems, which make it hard for them to read the text on the screen. Disabilities and chronic diseases prevent seniors from using the modern technology. Seniors with arthritis might find it challenging to handle the technology. It is a challenge for seniors with painful joints to use the computer mouse or type on a keyboard.

(2) Psychological barriers. If there is no assistance for them, seniors will find it very hard to learn the technology by themselves. According to the Pew Research Center, only thirteen percent of seniors who do not have the smartphones, tablets, or e-readers feel comfortable to try new technologies. Some seniors care about other people's opinions about them and think they will give others a foolish impression of themselves. Some seniors hold the idea that technology is always costly, which will also stop them from trying them.

Engaging Diabetes Seniors with Technology

We need to support seniors and teach them how to use technology. The community can offer teaching class to them and put computers in the libraries so they can hang out and explore it for a while. Family members also need to be involved in and teach seniors how to use digital devices such as smartphones and tablets, how to use social media tools such as Facebook and Skype.

As designers, we should build a bridge between high-tech technology and the seniors, combining the high technology with the specific characters of seniors in our design. We need to use high technology to serve them and make their lives much more relaxed and happier.

Figure 6 Engage Diabetes Seniors with Technology

The Aspect of Big Data

When users use the glucose meter to test their blood level, they want to know their history data based on the research. Taking advantage of the data can help them know their performance in recent days, weeks, or years, which can help them make some changes in the lifestyles or medications based on their data. They can show the data to their family members or doctors to help and give them good suggestions. Big data are data sets that are characterized by high volume, velocity, variety, exhaustivity, resolution and indexicality, relationality, and flexibility (Kitchin, 2013). Data has changed our relationship with the technology: without the maps and the human behavior data, there will be no self-driving cars; without data, we cannot predict the weather.

We can also use data to serve seniors diagnosed with diabetes. Except for the historical data to know performance I mentioned above, we can use data to predict what kind of and how much food senior patients can eat based on their sugar level. We can use the medicine database to help them. For instance, the system can show the pictures of various medications when they enter the medication name so they will not take the wrong ones.

Data Visualization

Present datasets with the information visualization way can help people easier to understand the data and perform the tasks more effectively. (Munzner, 2014). People prefer to read the data visualized by the colorful charts and graphs than the cold numerical spreadsheets. (Boicey, 2015). Human vision has the highest bandwidth and the processing power than the other senses such as touch, smell, taste and hearing. Using the information visualization technique to present the data can make full use of our most potent perceptual system. (Steele & Iliinsky, 2010).

Taking full advantage of image processing, computer graphics and human-computer interaction technology, combined with the human's visual and cognitive ability, we can get insights from data. Using data visualization to visualize the sugar level data can make it easier for seniors to know their condition since pictorial information is more understandable for people than the non-

pictorial symbols. Plus, images and videos are much more interesting than the cold numbers, and they can make seniors' everyday life happier.

AI Technology

If artificial intelligence is the car, then the data is the fuel. AI has been very popular in the medical area and has reduced the burden of many people who have chronic diseases. AI technology has many applications and great potential in the senior diabetes field for the following reasons:

1. The number of seniors who get diabetes is growing and seniors account for forty percent of the whole diabetes group.
2. More and more seniors can get access to new technologies such as smartphones and tablets.
3. Diabetes data can be tracked and recorded daily.
4. With many tracking technologies appearing in recent years, not only we can get data about glucose, but also we can collect more kinds of data like sleeping data, nutrition data, physical activity data and more.
5. With the availability of more data resources from social media, internet searches and diabetes complications, more and more data sources join the diabetes data pool, which is good for the management of diabetes.

AI has already had some applications in the diabetes area. Deep learning algorithms based on the large retinal fundus imaging datasets has made monitoring of cardiovascular risk factor possible (Fagherazzi & Ravaud, 2018). The diabetes data can be analyzed and converted into useful information for doctors and patients. There are already data sets used to predict type 2 diabetes. For doctors and patients, AI technology can help with decisions about the exact time for insulin usage, can help them determine which kind of food and how much patients can eat, can be useful in providing patients with advice about measures they need take according to their glucose level, and more. To sum up, AI technology will offer great support for seniors with diabetes and make their lives much more manageable.

Summary of Literature Review

Throughout this literature review, I have learned in depth about diabetes, especially for seniors with diabetes. I realized it is tough for them to manage their diabetes because of their physical and psychological limitations. Their functional impairment increases the possibility of getting balance problems and muscle atrophy which will affect their physical activity, increases risks of falls and make the doctor's visits inconvenient; Their cognitive impairment will affect their ability to compete tasks such as glucose measurement, medicine-related decisions, and good diet maintenance. Multiple medications bring them a financial burden, problematic interactions and drug side effects. Depression due to living alone and feeling isolated will cause a lot of problems such as difficulty in self-care, making healthy choices, mortality, and dementia.

Luckily, a lot of smart technologies such as AI technology, big data analysis, IOT (internet of things) have been applied to the diabetes area to make diabetes management much easier than before. Although more and more seniors tend to use the technology and have positive attitudes toward it, these products are not specifically designed for them. Seniors have their own characteristics: their vision impairment will make them hard to see the small texts on the screen; their memory loss will make understanding the complicated steps impossible; a hearing loss makes them hard to hear the low voice. When we design products, we need to consider the characteristics of seniors to make these technologies much easier to use. Only in this way the designers can narrow the gap between seniors and the technology to make their lives easier and happier.

METHODOLOGY

In order to provide both creative and user-friendly product for the seniors, I have used multiple methodologies in my design process. The first and most important thing is to know users' real needs and problems as the whole design direction is very important since it will determine whether my design is successful or not. Therefore, I have spent more than one semester to do the research. Although diabetes has become a widespread disease, I did not know the disease deeply before this research. At first, I went through a large amount of the related literature to learn about diabetes: what is diabetes? What are the treatment options for the disease? What are the technologies related to the disease? What are the medicines used to treat the disease? What are the diabetes conditions for the senior group? What are the characteristics of the senior group physically and psychologically? After the literature review, I had a deep understanding of diabetes and the senior group, which also made me well prepared for the interviews.

During the user research, I attended the diabetes education event in Lafayette several times and interviewed several seniors during the diabetes event. I volunteered in the retirement village in West Lafayette every week to get familiar with seniors' problems, wishes and needs. I also interviewed my grandfather since he also has diabetes. Market research is also an excellent way to know about current diabetes products and technologies in the market, so I also conducted market research. For example, I conducted the peer products research to know the current diabetes apps and glucose meters which had helped my design a lot.

Design development is a critical stage for coming up with good creative designs. During this process, I used the brainstorming, sketching, affinity diagram, HTA chart, and wireframing methods. Sketching and affinity diagram are good ways to come up with a large number of ideas. Therefore, I conducted several rounds of sketching and affinity diagram during the ideation stage. After the brainstorming stage, I used the HTA chart and wireframing methods to organize selected designs, trying to put all the design elements in the right approach. Then, I began the interface designs and physical designs. To make sure my interface and physical designs are good, I conducted the usability testing to test my designs and then made some changes and

improvements. At the end of the design stage, I used the usability testing methods to evaluate and refine the user experience design.

Identify Problems

When people talk about the user experience, beautiful, easy-to-use, fashion and more will come to their minds. However, these product features are just a small part for the product design. The core of user experience is uncovering the problems users meet and trying to find good solutions to that. Only by solving the problems and needs, we can make the product meaningful and successful (Blaase, 2015). In order to find problems, I reviewed a large body of literature, conducted market research, user research, and case studies.

Literature Review

The purpose of literature review is to put our research in a wider context so that we can build the relationship between our topic with other related areas. By literature review we can find out the area that previous studies haven't dabbled in which can be opportunities for future research. (Oliver, 2012). Literature review can make authors quite knowledge about the area they are studying, provide support for new findings and help us learn the methods other researchers have used.

A literature review helped me understand the research condition and the technologies in this area, which is also a good inspiration for me to design. Literature helped me know about the disease in depth: I know the reason not only why patients get the diabetes, but also how can they deal with this disease. Exploring the related literature helped me understand the diabetes epidemiology and pathogenesis in seniors. Going deep into the diabetes disease, especially in older adults, would have helped me with my interviews and design later. Literature review taught me some research and design methods to help me design and research better: a lot of evaluation methods like cognitive walkthrough, usability testing, and heuristic evaluation can help me evaluate and improve my designs. Some design principles like "problem first, features second" theory taught me to put the problems in the first place when I design.

Market Research

Market research is also very important since it helps the researcher understand what similar products look like and how they perform. Through this procedure, I can make sure my designs have good competitive advantages over the other products. There is a large number of glucose meters on the market, and the technology of glucose meters changes almost every year. New technology used on glucose meters makes them more and more user-friendly. Conducting market research can help my design bring a better experience to users than those in the market and make sure the technology used in the design is not outdated.

User Research

User research is the process of studying users' needs, wishes and characteristics to help our designs meet users' needs and bring benefits to users. (Schumacher, 2009). User research includes usability testing, questionnaire, research, and so on.

When we design, we should always put the users' wishes, needs, and problems first. User research is very critical to provide users with a wonderful experience. There are several ways to conduct user research, including user interviews, online surveys, etc. A direct dialogue with the users is a very rich and efficient way to obtain data which tell designers much about what they need to do include users' feelings, wishes, and needs in design. The other advantage of direct dialogue is when we interview, we can observe participants' behaviors which can also provide some useful information. During this project, I attended several diabetes education events in Lafayette and volunteered at the retirement village in West Lafayette. When I interviewed the patients, not only had I gained knowledge about their needs and wishes but also I got some design inspirations from them.

Case Study

To better know and experience real diabetes products, I also used the case study research method. A case study is a deep studying a particular problem. It can help researchers to narrow down their research into the specific topic. The case study can also be used to test how our models work in the real world. (Devi, 2017).

I bought three diabetes meters, including traditional and smart ones, and tested my blood sugar level every day. I kept a diary to record my feelings and ideas for later analysis. The most impressive experience was that it was very uncomfortable to hurt my finger to test every day. Through interaction with these meters every day, I got to know these products in more details. I found that the smart apps are not suitable for seniors as they are still too complex to use. The texts on the app are too small for them to see clearly. However, the traditional ones do not take good advantage of data. In my opinion, all of them can be designed to be much smarter but simpler to use.

Solving problem

During design development, I used sketching, affinity diagram, HTA chart, and wireframing to come out and organize my ideas.

Sketching & Affinity Diagram

The ideation stage is a time when I tried to come up with a lot of creative ideas. In this stage, we not only need to come up with as many ideas as possible according to our goals but also need to confirm and choose some good ones. There are lots of ways to explore ideas, such as mind mapping, sketching, and affinity diagram. I used an affinity diagram and sketching in this stage. Affinity diagram is a bottom-up way to group the similar ideas which have the same themes together. (Beyer & Holtzblatt, 1997). Affinity diagram is a useful way to help us organize the different ideas into groups according to their relationships.

I had two rounds of affinity diagram to come up with as many ideas as possible. Some Seniors and my classmates helped me with that in the first round. More people lead to a wide variety of ideas, and we can get inspired by each other’s ideas. Later, I also did that again by myself and organized the ideas under different themes.

Sketching not only can help us communicate our ideas to the others but also can help improve and evolve our concepts in the quickest way. During this project, I had many rounds of sketching in the ideation stage. Even in the design stage, I sketched a lot to come up with creative and

exciting interfaces. Seniors in the diabetes event and my peers in class helped me a lot and provided me with a lot of valuable suggestions to pick up good ideas for further development.

HTA Chart

Hierarchical task analysis (HTA) was then used to organize the structure of the whole system. Before we build an HTA chart, we need to be familiar with users and the system they will interact with. After we understand the tasks users need to fulfil the certain target we can build the HTA chart to explore the best solution. We can break down these tasks into multiple levels of subtasks. HTA can let us compare different solutions to the same task and choose the best one. It can also help designers understand how the system works to get an effective UX design. Hierarchical task analysis requires us to understand users' tasks and we can achieve this by:

(1) Understanding seniors' goals, wishes and problems.
(2) Figuring out and detailing the steps to achieve their goals.
(3) Comparing and optimizing different solutions and choosing the best one. (Hornsby, 2010).

Thorough HTA, I broke down the steps of seniors' interaction with the app system into multiple levels of subtasks, and analyzed them and optimized these procedures to make sure the whole structure is reasonable and the interaction process is fluent.

Wireframing

Wireframing is the final method I used before designing interfaces. It is a way to structure all my ideas, including the hierarchy and the key elements. Wireframing is useful for us to communicate with other designers, developers, and stakeholders about our design ideas. Once the whole structure was correct, I began to conduct my interface designs. I used digital illustrations to draw my diabetes app and then communicated with my classmates about the structure, making sure the whole structure is excellent and creative.

Testing and Validation

To make my designs meet my users' needs, I used usability testing method to test them. At the end of the design phase, I also used the heuristic evaluation method to refine and improve my design.

Usability Testing

According to Nielsen Norman Group, if you want only to use one method to test your designs, it should be qualitative usability testing. Usability testing is a process that you employ several participants as representatives of the target user to use and evaluate your product according to the usability metrics. (Rubin & Chisnell, 2008). Usability testing can be conducted during the design process to find the problems to improve our designs. It can also be conducted in the end of design process evaluate our designs. There are four steps during the usability testing:

(1) Preparing testing. Preparation is key to the usability testing success. Before usability testing, you need to consider the place, test participants, testing objectives, and metrics.
(2) Facilitating testing. During the testing process, we need to observe the users, take notes, and interview users to get their feelings and thoughts when they use the product.
(3) Analyzing data. After the usability, we need to analyze all data we get from testing and try to conclude the problems or solutions.

The main goal of this testing is to find problems in my designs, observe their satisfaction with the products and also collect these data for further analysis. Gathering these data including feedback from users can help me to create a good experience for users.

To evaluate the interface designs, I used the paper prototyping to test. Prototyping should be a necessary part of our design process in order to deliver a good user experience. The website, usability.gov, describes that a prototype is a draft version of the product that can be used to show users our general design ideas and explore our design ideas before we invest our time and money in developing the products. A prototype can be anything from low-fidelity prototype such as paper drawings to high-fidelity prototype such as interactive prototype made by the software. (“Prototype,” 2016). It is also stated by usability.gov that paper prototype is the quickest and easiest way to get the feedback from users about our design, content, and structure. (“Paper Prototype,” 2016).

There are two rounds of usability testing in my design. In the first design iteration, I printed out the app interfaces and also made some mockups for physical products. Then, I brought all these to test among seniors. When they were testing the paper prototyping, I observed them and took notes. Then, I collected this data back and analyzed them to improve my designs. After I finished

the final design, I brought the interactive prototypes and the final physical model to test among seniors. I will discuss this in more detail in the usability testing chapter.

USER INTERVIEWS IN EVENTS

A series of user interviews were conducted in the user study. A direct dialogue with users is more efficient and can give us useful information by observing their body language and their dialogue.

Diabetes Education Event

Attending the Diabetes Events

Fortunately, there is a diabetes event every month in the Franciscan Living Center in Lafayette, Indiana. Franciscan Living Center offers a diabetes education series throughout the whole year. They invite an expert every month, and the topics are different. Some of the topics are: (1) “Take Valentine’s Day to Heart”- where participants will learn exercises for a healthy heart. (2) “Meals Made Easy for Diabetes”- The plate method for successful meal planning is taught. (3) “Eat Better and Spend Less”- Learn recipes and tips to stretch your dollar. (4) “Sweet and Savory”- Explore flavorings and sweeteners to jazz up your favorite foods and beverages. (5) “Numbers That Count”- Learn numbers that are vital for our health.

I attended these events several times and learned a lot more about diabetes. Plus, when I listened to the literature, I could understand their concerns, observe their behaviors, and chat with them afterward. I found that this event is really critical to them since it is the only resource they can get in this town. I realized that they actually had a lot of questions and really cared about their health. I also found that they need to meet together to communicate with each other and support each other. Some of them were really experienced at controlling their sugar level, so others could seek help from them. Some seniors couldn’t move very conveniently but were still glad to attend the events every time (sometimes I even became a volunteer there to get water for them when they needed water, opened the car door for them, and so on).

It is strange that each time there are only around ten seniors coming here for the diabetes education. According to their answers, some of their friends have given up and do not really care about their health at all. The other problem is that the meeting is only one hour long. It is too

short, especially for seniors, for them to learn and some of the events took even less than an hour. Some of the lecturers only read through the slides one by one, which is too boring and I could even see some people nod off in the event; Also, seniors couldn't always catch up with the lecturers since they needed to spend a lot of time on taking notes. However, they could still get benefits from the event because they share the resources each time. For example, one senior working in the Franciscan Living Center could offer much help to the other seniors.

Interview with Diabetic Seniors

After the diabetes education event, I conducted several interviews with diabetic seniors. Through chatting with them, I found that some of them use smartphones and iPads. They always watch diabetes-related videos on YouTube. Almost none of them don't live with their children, and it seems that their children do not care about their disease, which makes it very hard for them to get the useful information about diabetes as the seniors are not so good at technology. The common problem is they do not know what to eat, and some of them even dare not to eat anything. Almost all of them hate the traditional finger prick blood testing because it hurts their fingers every day. Seniors have a hard time to see doctors: for example, one of them had a problem in her spine, and she used a walking stick to help her move (It takes more than ten minutes for her to move from downstairs to the main floor). Some of them are too heavy to move easily and the others are too aged, which make it inconvenient for them to move around.

Figure 7 User Interviews in the Diabetes Education Event

Retirement Village Volunteer

To better understand seniors' characteristics and wishes, I volunteered in the Westminster Village in West Lafayette. Westminster Village provides seniors with living housing, as well as assisted living, Medicare-certified skilled nursing, and memory support care. It is a really big village with thousands of seniors living in it. It offers seniors a lot of resources like libraries, art studios, gyms, cafeterias, and more.

I volunteered for the OMA (opening minds through art) project to teach them how to use different materials to create artworks. OMA project is designed for seniors with dementia since

art therapy can be used to take care of dementia patients. Art can improve dementia patients' cognition, behavioral & psychological symptoms and the happiness index.

I learned a lot about seniors: Firstly, their memory is pretty weak. My OMA partner cannot even remember things that happened in his life last week. When we volunteered there, we needed to put our name on a sticker tag and stick it to our chest to help them remember our name. We were also taught to use simple words and speak slowly when we talked to them. They also feel lonely because their family members live far away from them and cannot come to visit them regularly; Their daily life is a bit boring since they have spare time all the time. My partner had only one answer whenever I asked her what she did today: she said that she played music. Based on the policies of this assisted living facility, seniors were not free to go outside; It is also not very convenient for them to move, and many of them bring their walkers everywhere. My partner could not even find the right way between the art studio and her room when we walked together.

Figure 8 Volunteer in the Retirement Village Weekly

Relevant People Interview

Aside from interviewing seniors in the diabetes event and the retirement village, I also conducted some interviews with people whose parents had the disease because I wanted to know the diabetic seniors' situation from a different perspective. One of the interviewers is a male who lived only forty minutes away from his mother. His mother had had diabetes for 13 years and the

doctor was her only information resources. His mother had two other diseases besides diabetes: asthma and high blood pressure. Therefore, it was very hard for her mother to manage all these medications. He went there every month to help his mother put the medicine into different small cases. Also, his mother has vision problems, which makes it very inconvenient for her to see the doctors because she can only take the bus to see the doctor.

An interviewee's father in law also had diabetes. However, his father did not have a good awareness of how to treat the disease. He thought it is a common disease, so he doesn't need to see the doctors until the disease is too severe for him. He liked doing some exercises; however, ever since he got a fracture in his ankle, he cannot do his exercises anymore. He is not a fan of injecting insulin.

The most impressive interview for this study was talking to a nurse who nursed seniors for more than ten years. She provided me with a lot of good opinions, and one of my design features was suggested by her. She mentioned that seniors do not have resources for their disease, and the family doctor is not useful because they are not professional at diabetes disease. She suggested that the app should have a group function so that seniors can support each other. She also mentioned it is so strange that their children do not want to take part in helping them. When she was taking care the seniors, she found it is not convenient for them to see doctors, not only because they are over-weighted or too aged, but also because they need to wait serval weeks to see a doctor since the baby boomers have grown old and the number of seniors has increased significantly. However, the number of doctors has not changed. So there is an unbalance between the number of doctors and the patients. The final thing I want to mention is that seniors do not want to change their habits, and it is a problem I found out from seniors with diabetes and the nurse.

Name: David
Age:47
Location: West lafayette
Occupation: Uber driver

1/Got diabetes at 60 and passed away
2/Has a family doctor but need to see doctors when situation is severe
3/Went to see the doctor few times
4/Can't see clearly
5/Stop do exercises with an ankle crack
6/Inject the insulin two years before he passed away but dislike it.
7/Need to measure blood sugar every two or three hours

Name: Laura
Age:42
Location: West lafayette
Occupation: Caregiver

1/Worked as a nurse for seniors
2/Seniors don't have resourses
3/Unconvenient to see the doctors/a long waiting appointment
4/Children don't want to involve in
5/App can group them togehter to support each other
6/No medicine adoherence
7/Don't want to change habits
8/Family doctors are not very useful

Name: Steven
Age:35
Location: Chicago
Occupation: N/A

1/13 years long diabetes
2/Doctor is only infromation resources/wait several weeks
3/Live with her husband/her son often offers helps
4/Three disease/medicine problem
5/Vision problem
6/Scared to test/expensive

Figure 9 Interview Outcomes with Relevant People

CASE STUDY

Peer Products Analysis

After I did some research about the diabetes apps in the market, I found that there are no apps designed specifically for seniors. Additionally, I found that there are some challenges when seniors use these apps: The texts of some apps are too small which makes it hard for seniors to see clearly; For some apps, there are too many words in the interface which will make seniors feel overwhelmed; Too many steps and interactions in these apps confuse them.

When I studied these apps, they are not so smart. Although some apps have a lot of useful functions like recording the glucose data, exercise data, and food data, they cannot give suggestions based on these data. Intelligent technology can also make fewer steps and interactions to achieve the same target. For example, after entering the first characters of a medication name, the system can allocate the full name of the potential medication from the medication datasets and show up the name and pictures automatically.

Although these apps do not suit the seniors' needs, some of them really have many very amazing featured functions, which I can get inspiration from: The iHealth Glucose management app is the smartest app among them. Users can use the glucose meter to test the blood, and then, it will send the data to the app with Bluetooth technology. On the app, it uses the dashboard to present data which helps users understand the data better. Users can also check the history data to know their history performance. Another good function is that it provides users with learning resources which can make people with diabetes catch up with the latest technology and news; The mySugar Logbook combined a small game in it which can bring users some fun; Some apps like Sugarmate have several functions, including food, insulin, exercise, reading, medication and note functions. In my opinion, it is really useful since managing diabetes needs measures from different facets, so it is better to be an integral system. The pros and cons of most popular diabetes apps have been listed in the following pictures (see Figure 10).

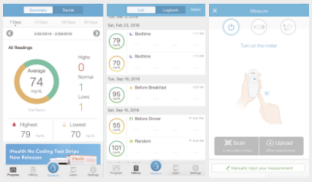
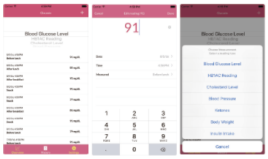
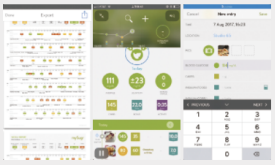
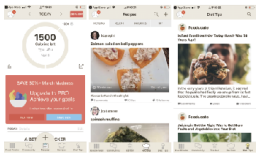
Diabetes Apps	Prons and Cons	
	Pros: 1/Use dashbords to show the data 2/Show history data 3/ Learning materials 4/ Bluetooth connecting	Cons: 1/Letters are too small for seniors 2/Bad Information visualization 3/Afraid to prick hand
	Pros: Use dashbords to show the data	Cons: 1/Too many steps and choices. 2/Letters are too small for seniors 3/Just show the data
	Pros: 1/Designs are good and interestring 2/Achieve goals with scores 3/Share report to the doctors 4/More information with more money	Cons: 1/Too many steps and choices. 2/Letters are too small for seniors 3/Just show the data
	Cons: 1/Community: almost no seniors 2/Too many steps and choices 3/Calorie calculation is not accurate 4/Children can't login in to support them	5/No blood sugar function. 6/No lessons for more information. 7/Can't solve mood problem
	Pros: Select the type of diabetes	Cons: 1/Just show the data 2/Need to pay $60 per year 3/No measures for blood sugar 4/No community 5/Not amied at seniors

Figure 10 Peer Products Analysis

Self-Measurement Experience

Diabetes products seem a bit complex and they are updated very quickly as technology has advanced a lot in this area during the recent decade. To better understand these products, I bought two blood sugar meters: a traditional one and a smart one.

Figure 11 Two Versions of Diabetes Meters

Although it is almost the same price as the traditional one, I first bought the smart app one. The smart one was released to the market in recent years, so I wanted to experience how smart it actually is. However, After I bought it, I tried many times to figure out how to use and failed. One month later, I gave up the plug-in smart meter and decided to buy the wireless one. Although I figured out how to use that, I did not dare to prick my finger to test. Several weeks later I decided to prick my finger to test because I had to do so. However, when I pricked my finger and put the blood on the strip, it still did not work. After trying and failing many times, I realized more blood was needed to test successfully. Then, I tried to test that different times every day: before meals, after meals and at random time. However, after I tested, I felt that it is a bit difficult to figure out these numbers. Consequently, I bought another traditional device because I suspected the accuracy of the smart one. The traditional glucose meter is much easier to use since it needs little blood on the strip and needs fewer steps. The disadvantage of the traditional one is that they cannot take good advantage of the data, which is very important for seniors with diabetes to better manage their diabetes.

During the whole testing process, I kept diaries every day for later analysis. In addition to the problems I discussed before, the skin area I always pricked will become hard which makes it harder to prick next time. Also, I always forgot to test when I was busy.

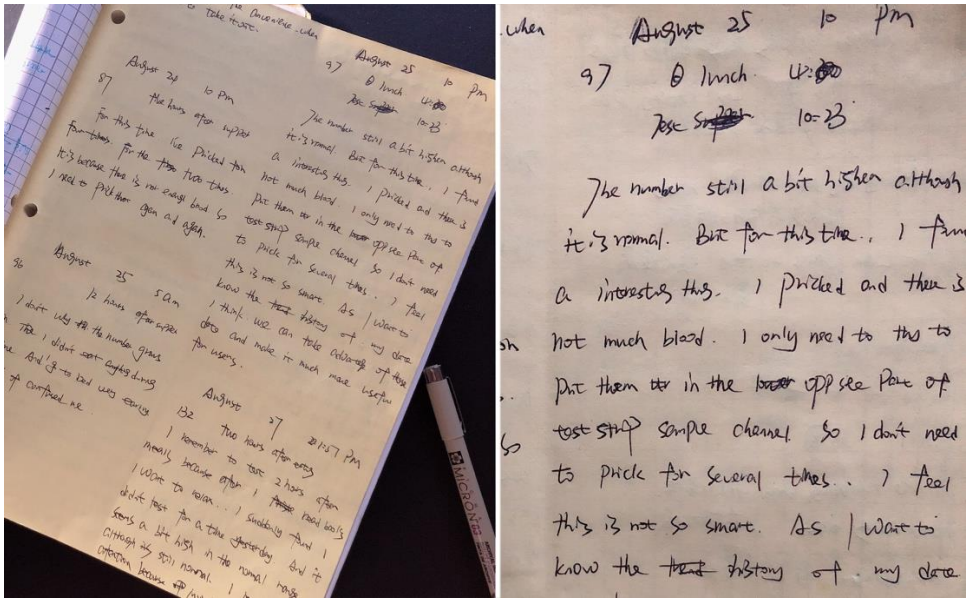


Figure 12 Diaries I Kept When I Test Sugar Level by Myself

Latest Technology in Treating Diabetes

The biggest challenge of the current diabetes meters is the pain and the subsequent uncomfortable feeling it brings to seniors. Except for that, the device is not portable since they have to bring the meter, the test strip, lancing device, and lancet with them which is also a burden on seniors' memory since they can easily forget to bring one or two things. Moreover, it is a complex and time-consuming process to conduct just one blood test. How can we solve these problems? Can we resort to high technology and make diabetic seniors' lives easier, more comfortable, and more convenient?

I researched the high technology, trying to find solutions from them (see Figure 13). The first technology I found was the molecular scan technology (it has already been applied in ChangHong H2 phone and Scio scanner). It is the material sensor that can scan and analyze physical objects. The material sensor can observe the light reflected from an object, break it down into the spectrum, and analyze it to determine its chemical information since every object has a unique molecular fingerprint. It can scan sweetness & body fat, authenticate pills, monitor blood glucose levels and more; Another technology is the biological sensor which is already developed by the Tokyo Medical and Dental University. Since saliva also contains the glucose, the biological sensor can detect and monitor real-time glucose levels in saliva and then send the

data to the phone by Bluetooth (Mitsubayashi, 2018); The final one is Kiss & Tell product which already exists in the market. Users need to put a cassette in the mouth until wet in the result area. Then, after five minutes they can check the pink color in the result area to know their glucose level. One bad user experience for this product is that users need to wait five minutes to get the result.

Figure 13 Latest Technology in Treating Diabetes

In my opinion, the molecular scanner and biological sensor technology can be included in the diabetes meter to improve seniors' experiences. With these two technologies, users would not need to prick their fingers to collect the glucose data. They will make interactions between seniors and the product much easier since they will reduce the steps to use the product. They will also make diabetes meter more portable because seniors only need to bring the diabetes meter and their smartphones.

Problems Found in Seniors Diabetes Treatment

After the user interviews and the dairy study, I collected and analyzed all the data to find the problems in it. All the problems found include: (1) There is a need for more supporting

information. (2) Testing the blood glucose level is not comfortable. (3) Seniors with diabetes feel awkward to test the blood in public. (4) Seniors with diabetes forget to test the blood sometimes. (5) Data can be used to treat diabetes better. (6) Seniors have a hard time figuring out different medicine. (7) Their vision problems can be an obstacle. (8) It is inconvenient for seniors to visit doctors. (9) Some seniors have no medicine adherence. (10) Seniors dare not eat anything. (11) Seniors with diabetes cannot do exercises when they have ankle cracks. (12) It is hard for them to change their habits. (13) The expense in the long run is expensive.

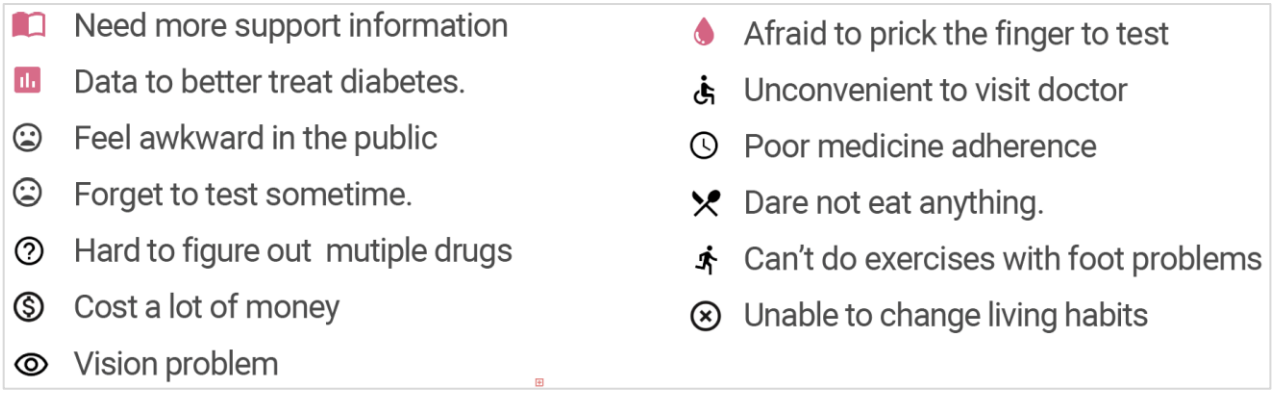


Figure 14 Problems Identified from the User Studies

DESIGN ITERATIONS

Good designs do not just appear in one day. They need many iterations to make them best suit users' needs. Iterative design means our design is a living project, requiring regular modifications and improvements during the whole design process.

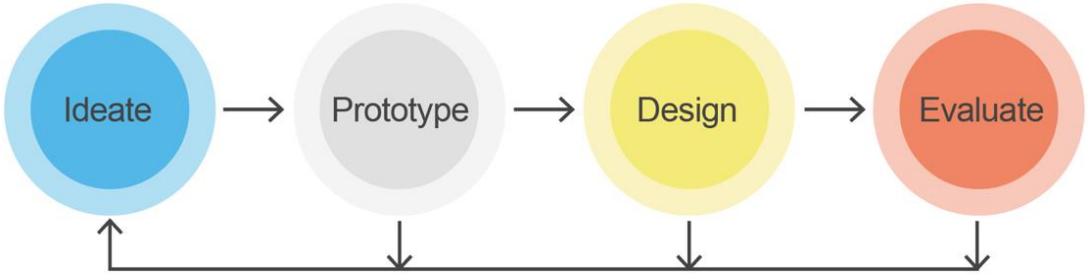


Figure 15 Design Iterations

Design iterations have many benefits: It can find the problems earlier during the design process rather than at the end, which will save our time, energy and money; It can help us get many feedbacks so we can know which part has the problem and needs improvement. During my design process, I had several design iterations. Every time I brought the prototypes (from low-fidelity prototype at the beginning to high-fidelity prototype in the final stage) to them, seniors could always give me really valuable suggestions and feedback to help me improve my design.

Design Ideations

Persona

A persona is a representation of the target users. It helps us sort out who we will design for and what their needs and wishes for this product are. It gives us real sights about our target users which will help us design the products that best suit users' needs and wishes. As you can see from the figure below, my target users are seniors with diabetes. The design goals are helping seniors to quickly get more information about diabetes, improving the blood testing experience, using the daily data and history data to treat diabetes.

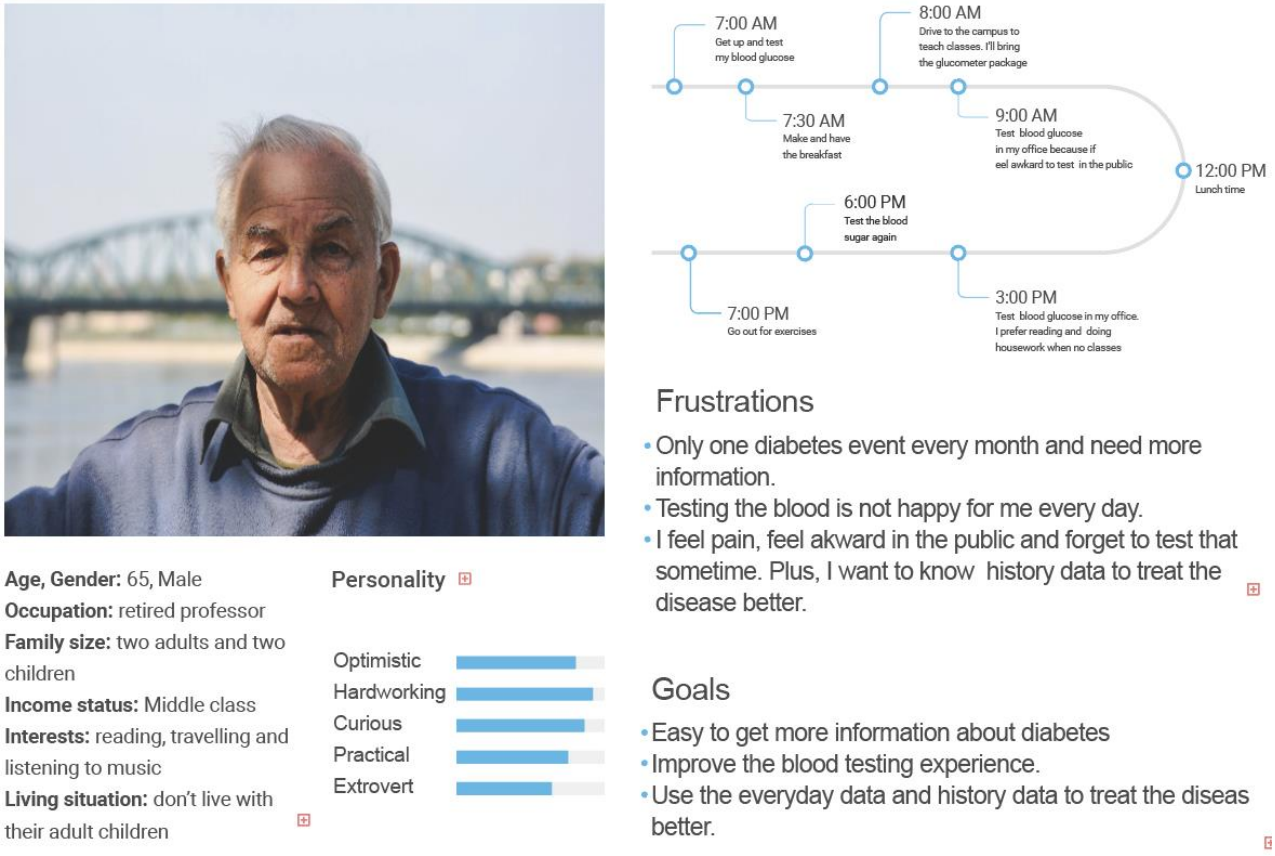


Figure 16 Persona of A Senior Person with Diabetes

User Experience Journey Map

To make sure users have a smooth experience during the whole process, I decided to use the journey map method. User journey includes several steps that map out how users interact with the products and services. There are two scenario types: one is how our users interact with the products and services currently. Another is how we want them to interact with the products and services. By using a journey map, we can understand how the users interact with the products and services and know the advantages and limitations in the workflows. When we build the journey map, there are the things we need to consider:

(1) Context: Who are the users? What are they doing? What is going on around them? What are the goals and targets for the users in each step?

(2) Sequence: What are the steps in the journey.

(3) Functionality: What's the functionality for each step?

For my project, I divided the user journey into three stages: pre glucose testing, glucose level testing and post-testing. For each step, I listed all the user feelings, thoughts, and the parts we can improve: When seniors bring the product, they feel that product package is a bit large since they include lancets, test strips, glucose meters and more. If seniors do not have to bring many items with them, it would be more convenient for them, so the package can be designed more portable. When seniors use the meter to get glucose data, they feel that it is awkward to do the test in public, and they are afraid to test every time because they need to puncture finger to get the blood. Therefore, the product can be designed in a way that people will not regard it as a blood sugar meter, and it can show how many times and when they have tested.

When users get glucose data, they prefer the infographic way to show data, and they think history data is beneficial. Therefore, we can use an infographic design way to show data: how many times & when they have tested, what the trends of data are and whether the data is better than before or not; After they get the data, seniors sometimes get confused about them and what they should do with the data. Therefore, it is better if the system can tell users intelligently what measures they need to take according to data. After they explored their data, seniors might have other needs like watching some diabetes videos that can educate them about how to treat diabetes better. Moreover, the app can provide more functions such as a group function so that users can talk in this group to support each other and can provide some resources like diabetes videos and news for each other to see.

After blood testing, seniors feel uncomfortable dealing with the bloody strip and the used lancets. It is better to make it easier for users to deal with the bloody strips and used lancets and the packaging process should be simple and time-saving.

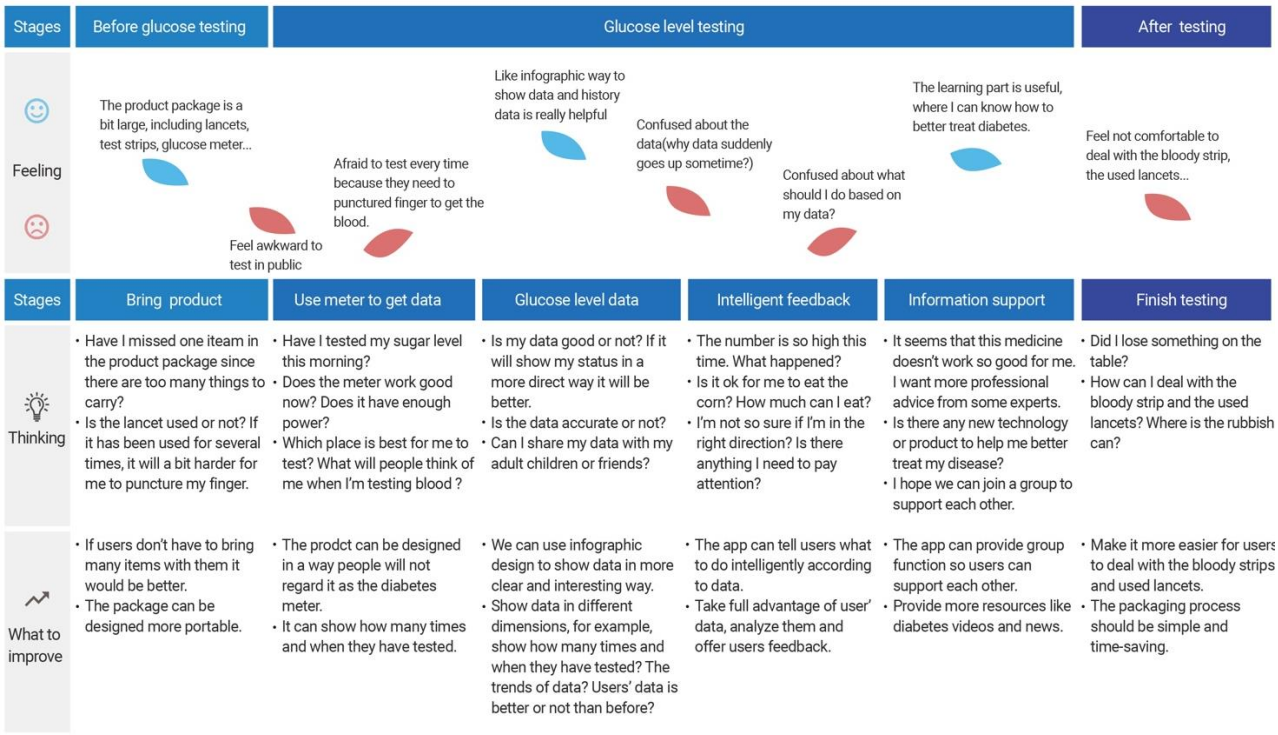


Figure 17 User Journey Map

Brainstorming & Sketching

Sketching is the best way to explore ideas. And the more ideas you get, the greater the possibility that you come up with the decent ideas. To solve the problems smartly and creatively, I drew as many sketches as possible. After talking with seniors about my ideas, based on the problems, I decided to design one glucose meter with the app.

The glucose meter is the essential product to seniors with diabetes as they need to measure their glucose data every day. Seniors stated that they liked the gum idea that when they chew the gum the system can get the data. The gum idea solves the problem that they feel pain when they prick their fingers to test their blood. Also, chewing the gum can bring them fun and make them feel relieved. Moreover, chewing the gum is good for seniors' memory, thus be suitable for dementia. For the diabetes app, the primary function is to receive the data from the glucose meter. Except for that, diabetes seniors like the group idea that they can join the group and support each other. Seniors also like the idea of resources that they can get learning resources from the app. Finally, they are fond of the idea that they can scan food to know how much they can eat.

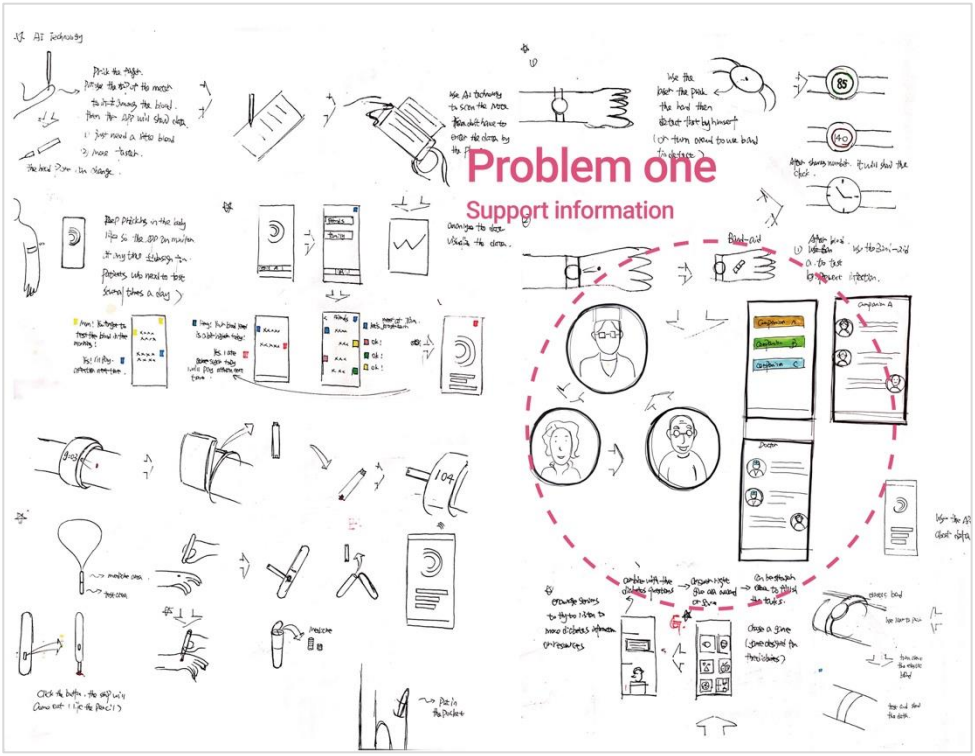


Figure 18 Problem One Sketch

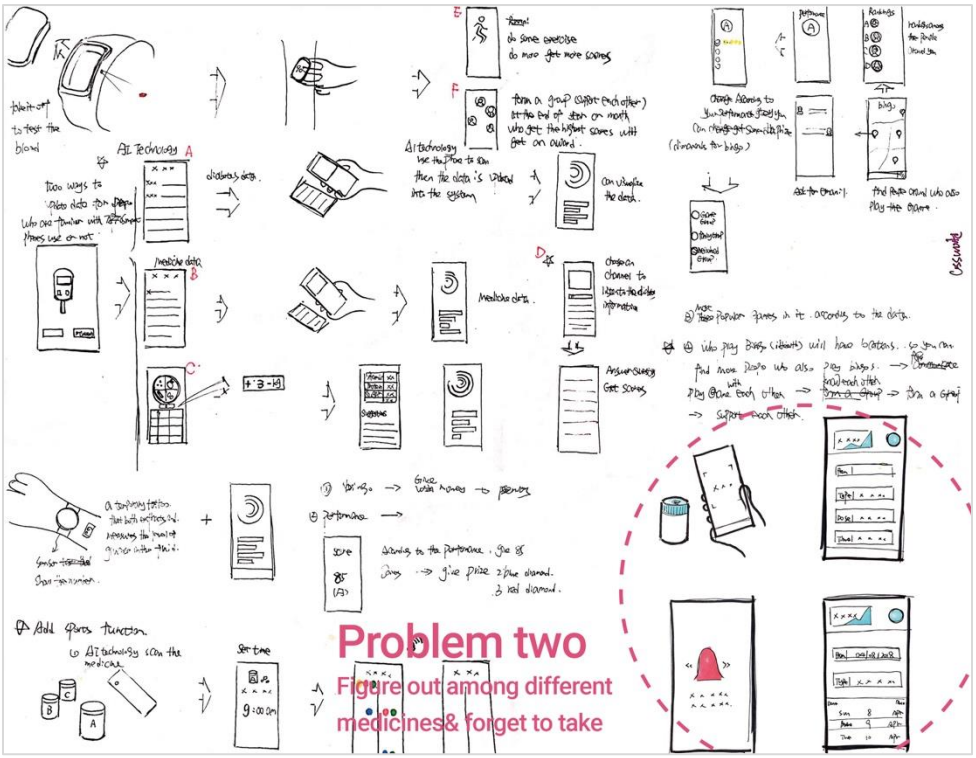


Figure 19 Problem Two Sketch

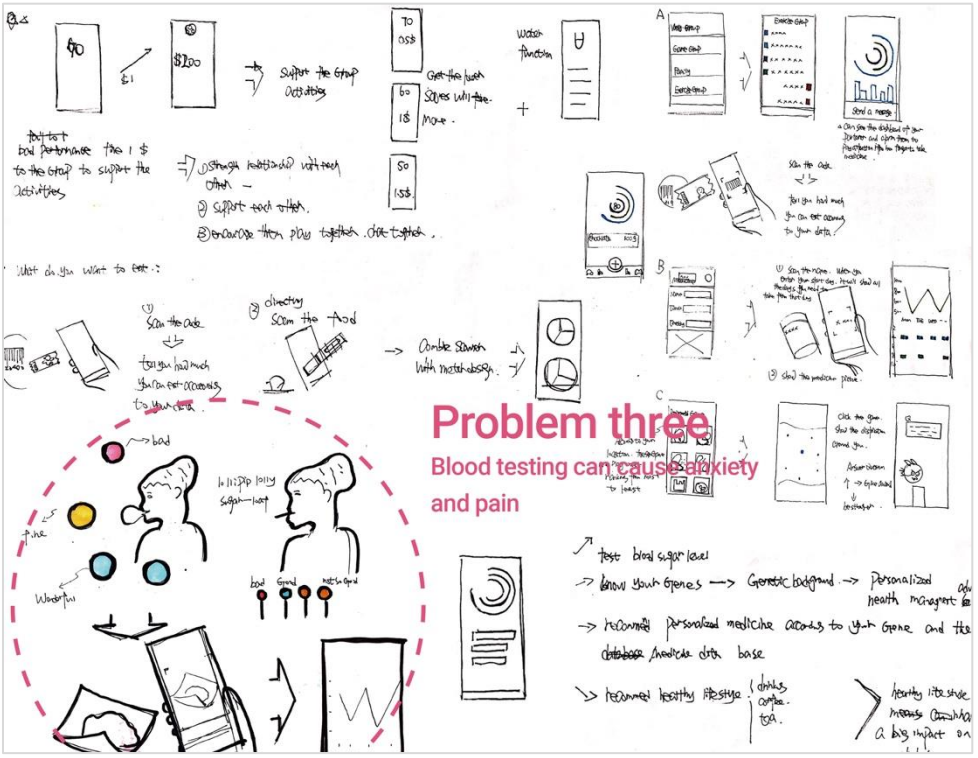


Figure 20 Problem Three Sketch

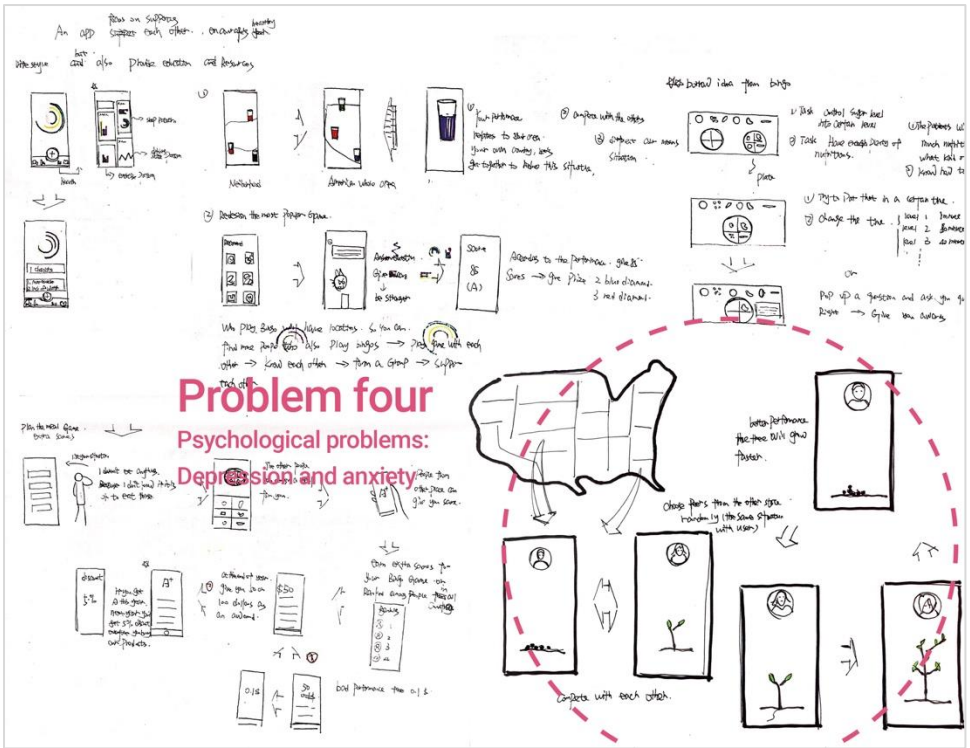


Figure 21 Problem Four Sketch

After a bunch of rough sketches and some potential ideas have been chosen, I began to draw the detailed sketches. I thought about more details among these sketches, including each interface details (what are the interfaces look like? What are the possible interactions?). I tried to explore the more technological details such as which technology is better and how I can combine the technology into the product in a natural way.

Figure 22 Detailed Sketch

Design Development

HTA Chart

As I mentioned in the methodology chapter, Hierarchical task analysis (HTA) was used to organize the structure of the whole system. By HTA we can learn users' tasks needed to fulfil the specific goals. (Hornsby, 2018). To make sure the whole structure is excellent and the process is fluent, I divided the system into four subtasks: the measuring task, the data task, the reporting

task, and the group task. The first is the measuring task: Seniors with diabetes can use the glucose meter and then the data be automatically sent to the app. Seniors can also enter diabetes data manually. The second is the data task: Diabetes seniors can check the data on their app. They can see both the daily data and the history data. The third is the reporting task: Seniors can see the sugar level report, their sleep habit report, and their daily activity report. The final one is the group task: Seniors can choose to join the group on the app, and then, they can ask questions, do exercises together, and share diabetes resources in the group.

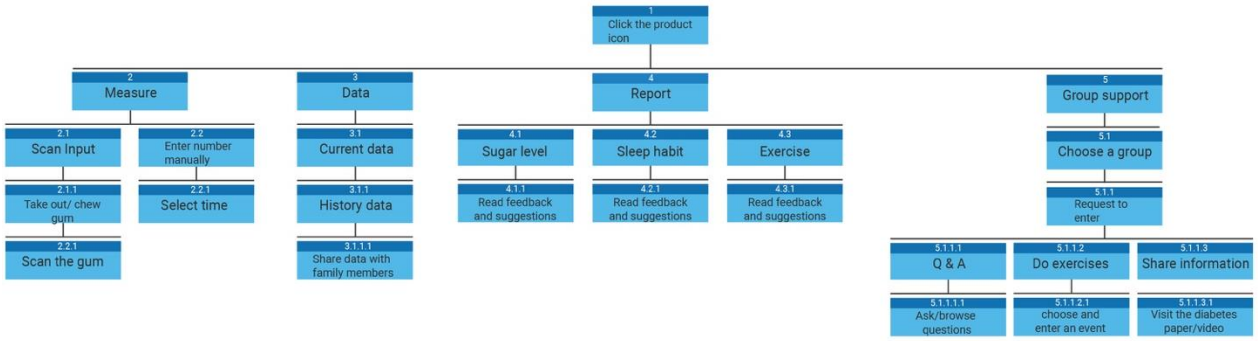


Figure 22 HTA Chart

Wireframe

After the whole structure is decided, I used the wireframe to layout the interface elements. Since the target users are seniors with diabetes, I tried to use figures and graphs instead of text as much as possible.

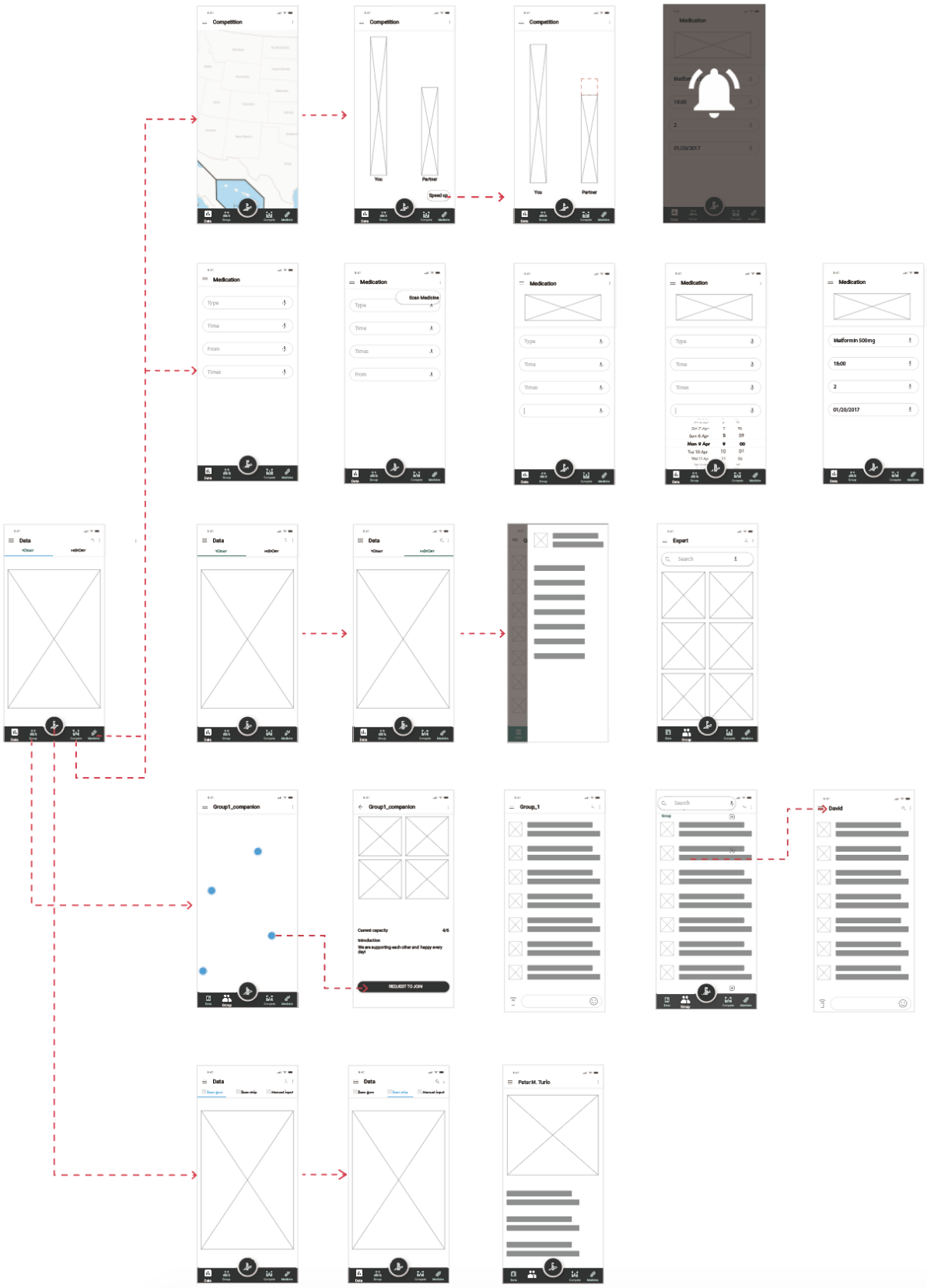


Figure 23 Wireframe

Senior Colors & Fonts Study

As seniors grow older, their eye lens and cornea yellow and darken, eye pupils will shrink and have light scatter and limited visual field. It is hard for them to distinguish the colors because colors like blue, green, red, brown will become muted. And when two colors are put together, seniors can't figure out a similar color like green and blue. So the colors used should have high contrast. When seniors age, they will experience loneliness, so we need to use the colors that can give them a warm and harmony feeling. Plus, using a variety of colors will be suitable for their cognitive function, and the bright colors are good for acuity loss (Coleman, 2017).

Below are the six most favorite colors among seniors (see Figure 25). Blue is the seniors' favorite color since it can remind seniors of water, which can make people feel more at peace. Blue is a calming color and can also help reduce stress.

Color	Reason
	Studies show that shades of water and beachy blues help make people feel more at peace. It's a calming color and tends to reduce stress.
	Earthy and forestry greens are known to promote healing, relaxation and serenity.
	Red is known to be a stimulating color that signifies strength and alertness.
	Yellow is often associated with happiness and is seen as a cheerful color.
	Light and bright shades of white and cream promote hope and spirituality. It's also known to be cleansing and calming.
	Earthy tones and espresso shades of brown are known to stimulate balance.

Figure 24 Most Favorite Colors of Seniors

During my volunteering in the retirement village, I've interviewed four seniors and three of them mentioned that they like the blue color because they prefer the colors from the nature, and the

blue color can give them a feeling of cleanliness. Therefore, blue will be the primary color in my project. The black color will be used for floating action buttons, typography, and iconography. The red color can be used as an error color.

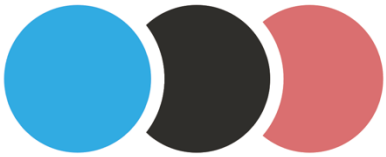


Figure 25 Color Used in Interface Design

For the fonts, we need to use the large and legible fonts. We should use at least 12-points fonts for the app design, and we need to let seniors be able to increase the text size as desired to improve the readability (Nielsen, 1994). However, since it will be harder for seniors to figure out how to increase the size by tools or through the browser, it is better not to use a font size smaller than 12-points.

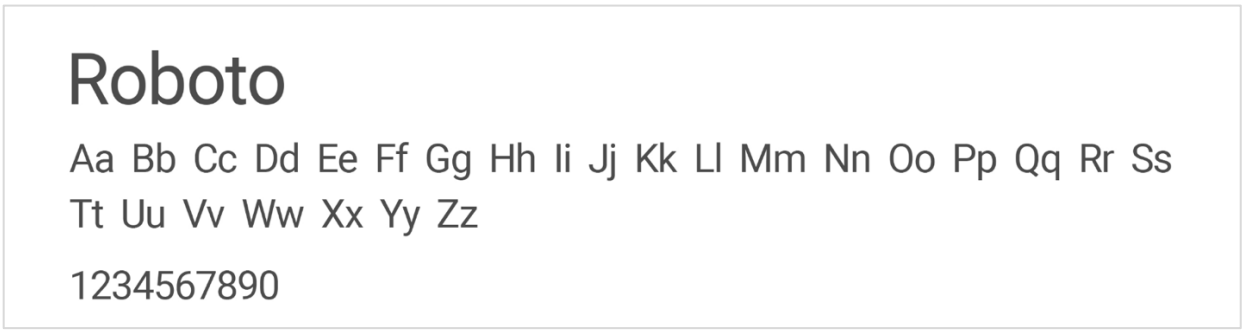


Figure 26 Font Used in App Design

First Design Iteration

In the first iteration, I finished almost half of the interface designs and the physical mockups, and then bring these to seniors with diabetes to get their feedback and suggestions. Plus, I got some professional design suggestions from my professors and classmates.

Interface Design Direction

I have three directions and will test them among seniors to see which direction is better. I am not so sure whether seniors like the standard design or the designs with more graphs, although according to theory seniors will like the design with more graphs because it will help them better understand the information presented to them.

I interviewed four seniors, three of which preferred the leaf idea. They thought this one was more interesting and easier to understand. They held the idea that funny and lovely things should be parts of their daily life. And during my volunteering there, I found that a lot of seniors feel lonely and bored. So interfaces designed with the interesting & funny elements can bring fun to their boring and depressing life.

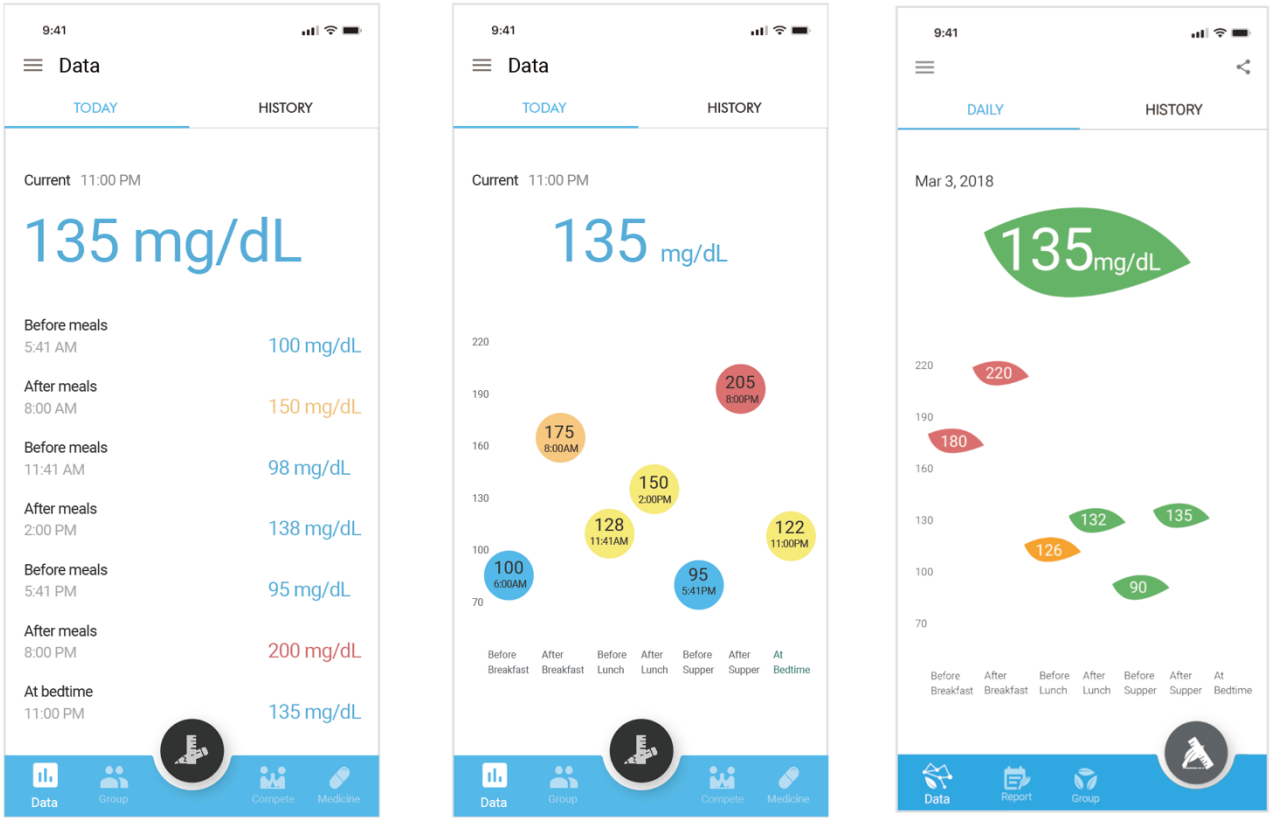


Figure 27 Three Interface Design Directions

First Iteration of Interface Design

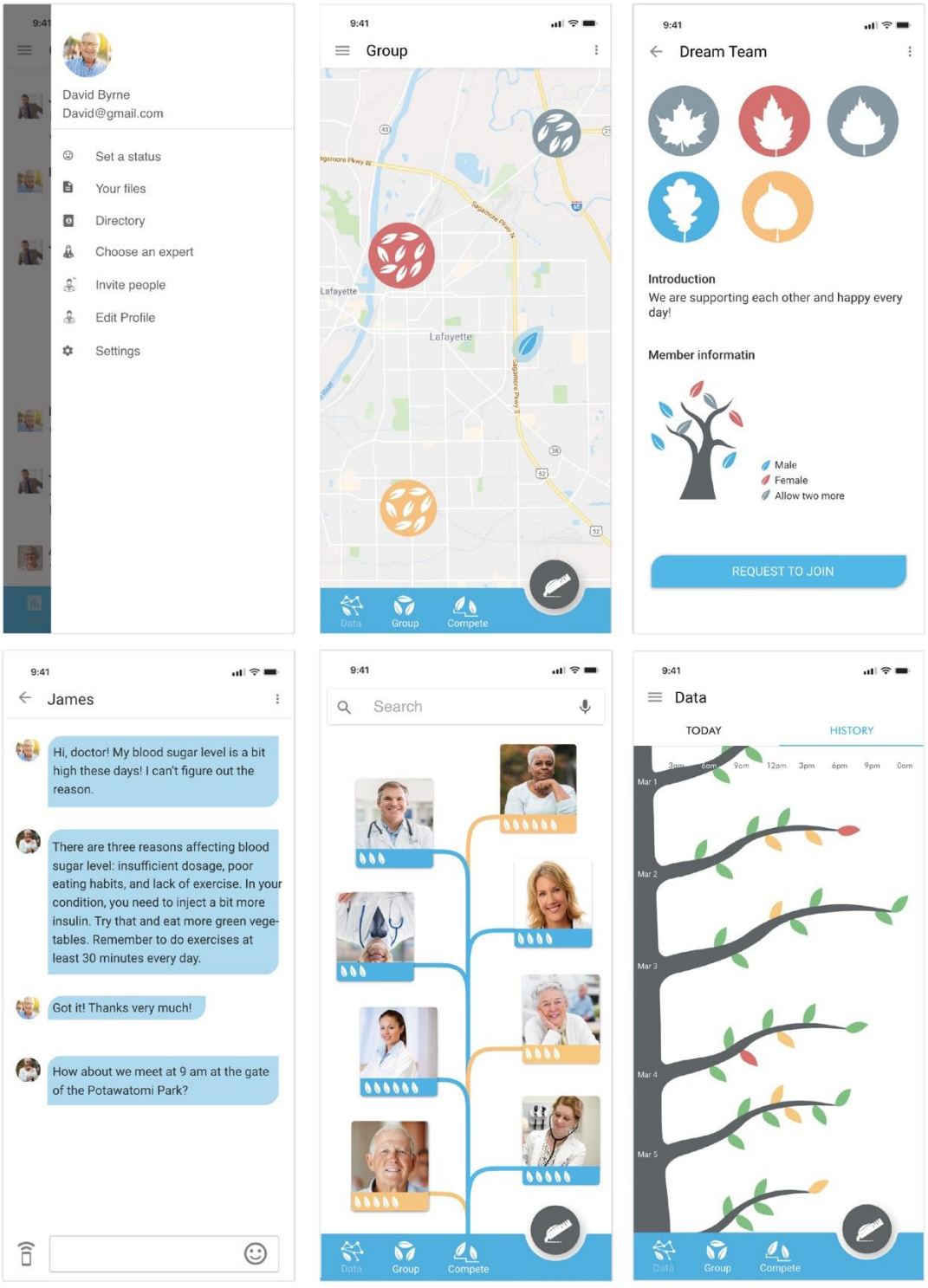


Figure 28 Part One of First Interface Design Iteration

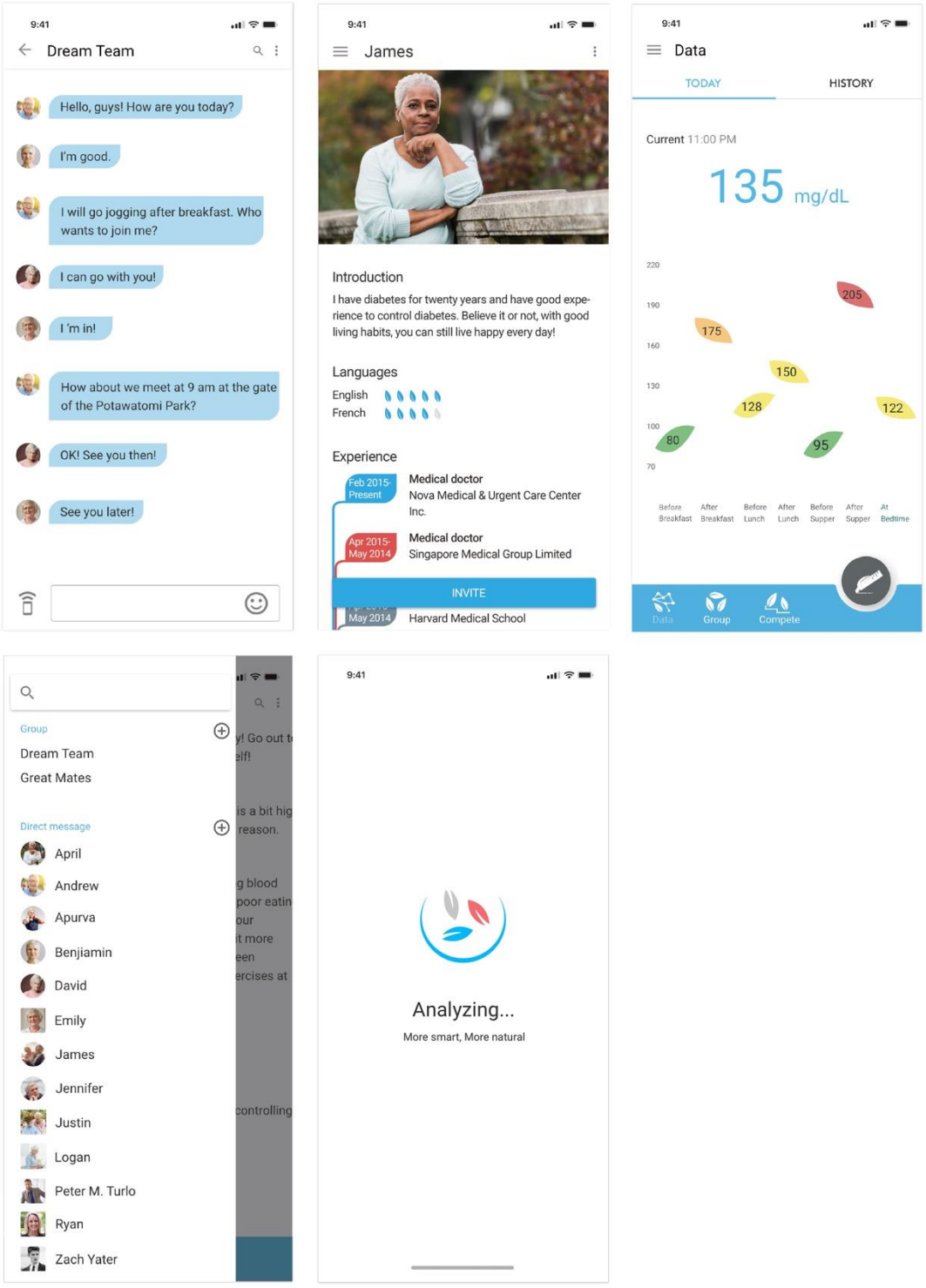


Figure 29 Part Two of First Interface Design Iteration

First Iteration of Physical Product Design

As I have mentioned before, two high technologies can be used in the seniors' diabetes glucose meter design: the molecular scanner and the biological sensor technology. I began to sketch again to explore how to integrate these two technologies into the product naturally. In addition, I tried sketching to find if there are more creative solutions that can be used to solve problems except for these two technologies.

Finally, after talking with seniors, we narrowed down to two design directions. One is combining the phone case idea with the biological sensor technology. The phone case can hold both the pieces of gums and the sensor part. Seniors can take out the gum to chew and then put the chewed gum into the spaces that have the sensor. The sensor can get the data and send it to the app; Another one is the scanner which can also hold pieces of gum. Seniors can take out a piece of gum to chew and then use the scanner to scan it.

Figure 30 First Physical Product Design Direction

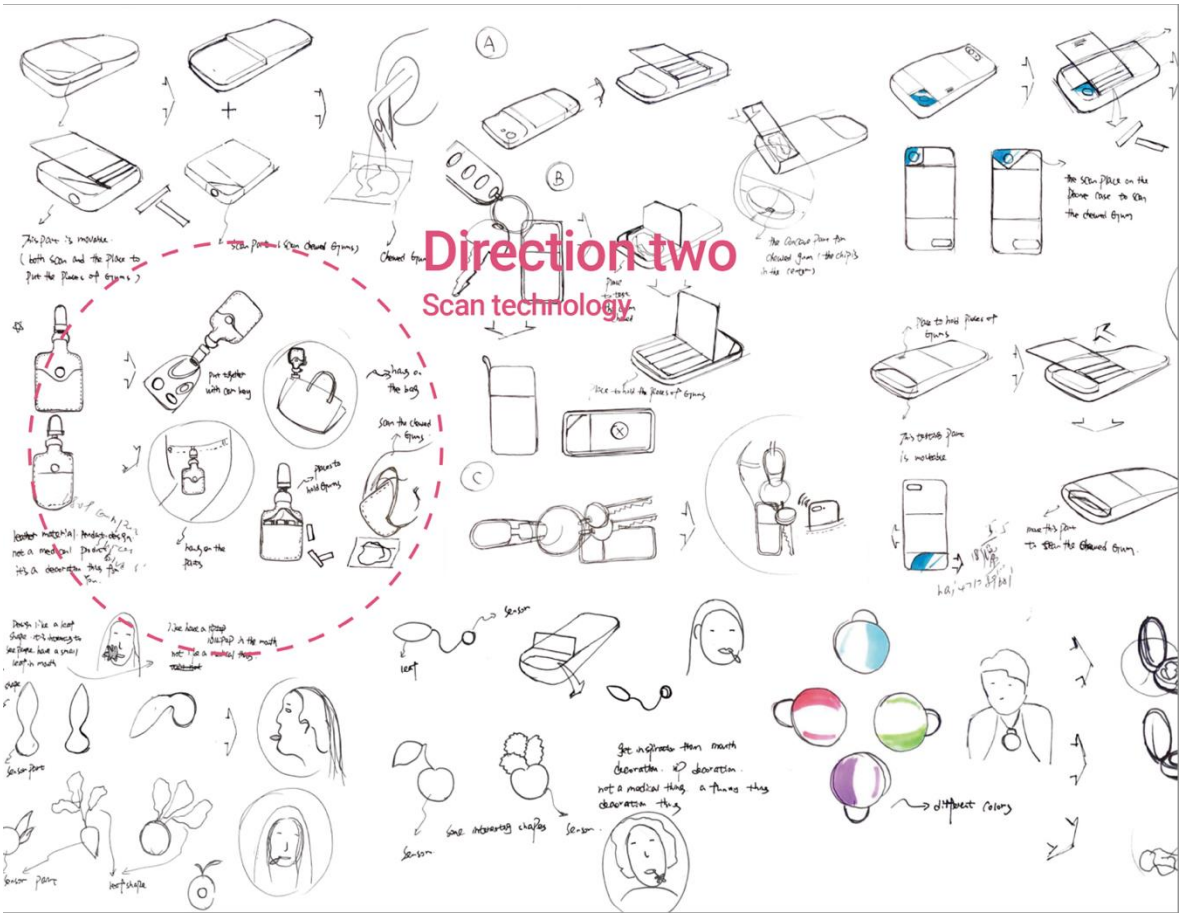


Figure 31 Second Physical Product Design Direction

Mockups of Both the Glucose Meter and the App Design

I built three models with Rhino for different directions. One is the phone case with biological sensor technology (see Figure 33). There are two parts in this phone case: One part is designed to hold six gum bears since seniors with diabetes need to test their glucose level six times a day. These gum bears can be washed to be reused. The other part is designed with six sensor areas. After seniors take out one gum bear and chew it, the chewed gum can be put in one of the sensor areas. Then the data can be sent to their app.

The second direction is the scanner model (see Figure 34). It is made up of two parts: one area for gums and the other area for the scanning part. There is a big scan button on the surface. After seniors chewed the gum, they can press the button and scan the chewed gum to get data.

The third model is the idea that I got inspiration from Kiss & Tell product (see Figure 35). After seniors chewed the gum and wrapped it with the provided paper, the paper color will change according to their glucose level. Then seniors can compare the paper color with the color bar on the surface of the product. However, I gave up this idea because seniors need to wait five minutes to get the result, and they think it is a waste of their time.

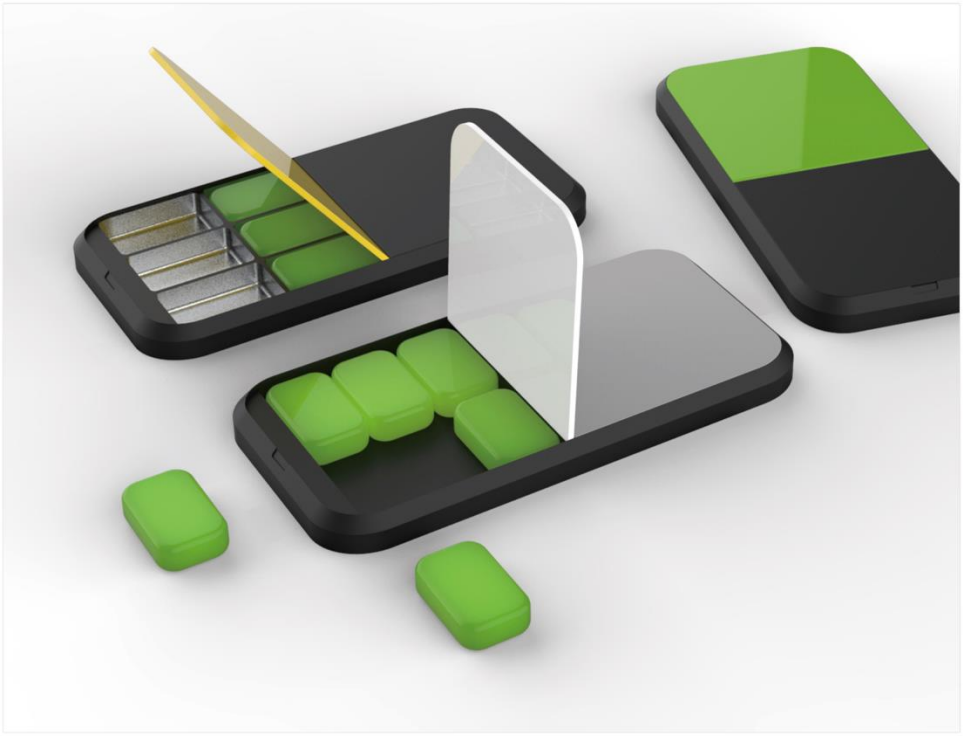


Figure 32 First Physical Product Design Direction

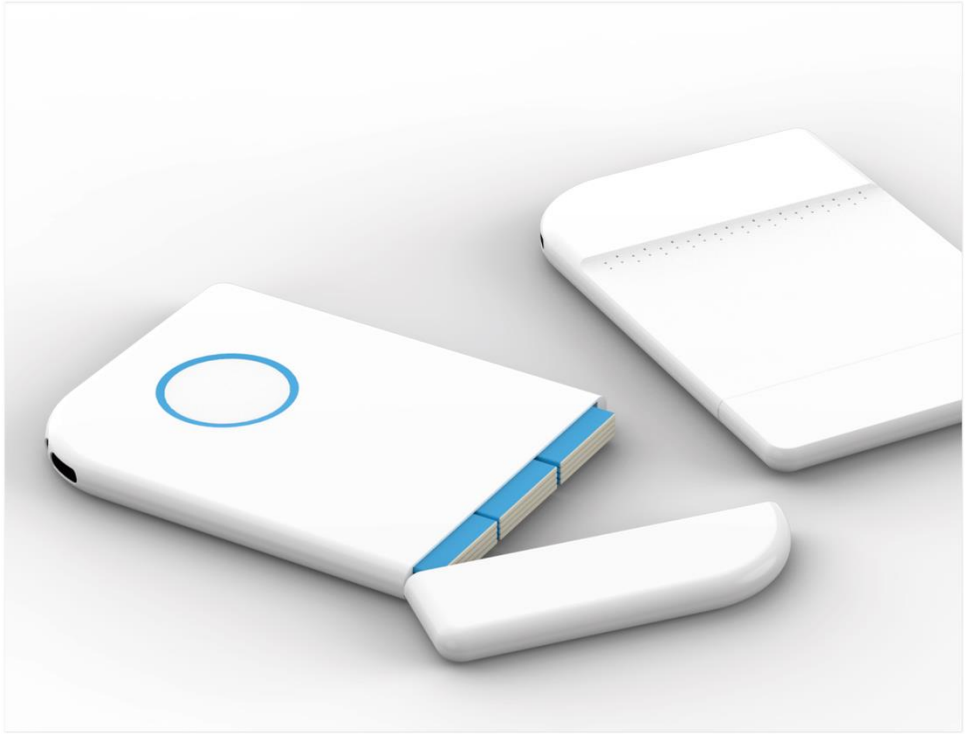


Figure 33 Second Physical Product Design Direction

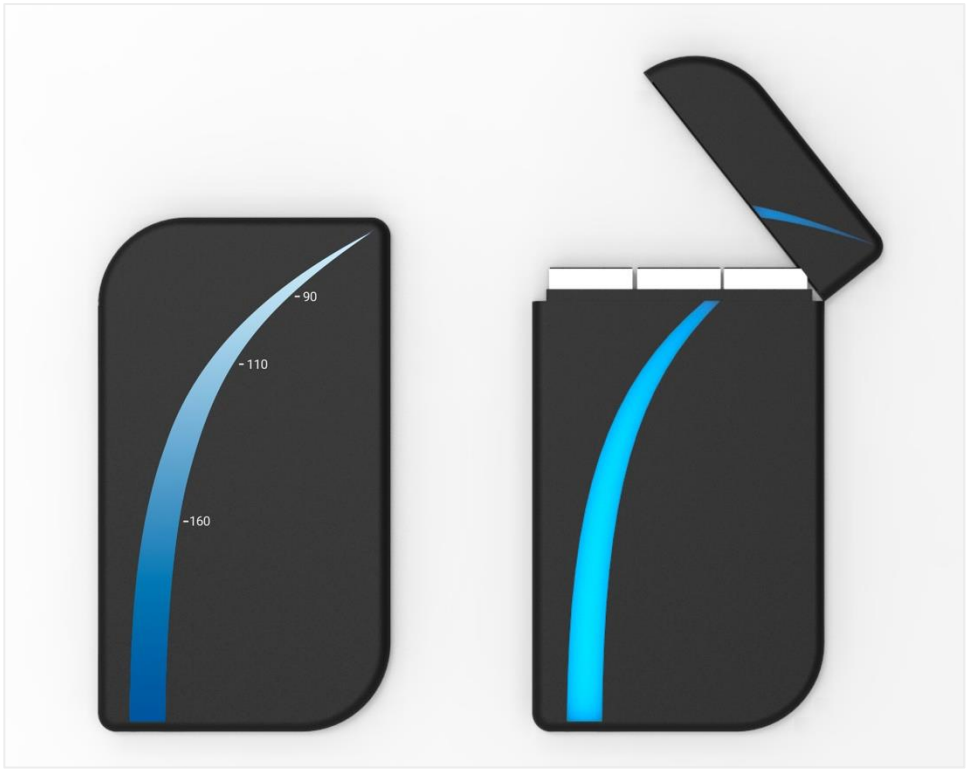


Figure 34 Third Physical Product Design Direction

Then I started to build the mockups (see Figure 36). I built different shapes and sizes for the phone case, the scanner, and even the gums. It seems that organic shape looks better and feels comfortable when people hold it. The gum bear size cannot be too large because of the limited phone case space. Too small gum bear will make seniors easily swallow it which should be prevented.

Figure 35 Second Physical Product Design Direction

Product User Testing

I brought all the mockups of both physical and digital designs to the diabetes event in Lafayette and the retirement village to do the usability testing. I interviewed six seniors (Figure 37).

There were three goals in this usability testing: (1) to decide the design direction for the app design. As I have mentioned before, there are three directions for my app design, including the standard design with letters and numbers, the information visualization design way, and the more creative design combined the leaf idea with the information visualization way (see Figure 28). (2) to decide the design direction for the physical product. I needed to test which technology, the biological sensor technology or the scanning technology, is better for seniors. (3) Get the feedback and suggestions for both the app and the physical product.

Figure 36 Second Physical Product Design Direction

The seniors I interviewed were really nice and gave me a lot of feedback and suggestions. Considering their feedbacks, for the app design, I decided to choose the “leaf” idea. According to

their feedback, the designs with information visualization way are easier to understand than the normal design. Also, they think the designs combined with the leaf idea and the information visualization way are more attractive.

For the physical design, I finally chose the one with scanning technology. It is a bit uncomfortable for seniors to use the designs with the biological sensor technology because they need to wash the gums and reuse them. Also, it is more complex to use than the designs with the scanning technology. The scanner design is straightforward and easy to use. They also gave me the other valuable suggestions: The gum should have no sugar in it. It can be designed into the leaf shape to be consistent with the app design. Some texts are a bit small and hard for them to see clearly. The group idea is useful to them as they can make friends and support each other. It is useful to have videos in the app for them to study and learn about diabetes management. All the feedback and suggestions are listed in the following chart (see Table 1).

Table 1 Feedback from Usability Testing

	Negative Feedbacks	**Positive Feedbacks**
App	1/ The letters are a bit small. 2/ You can have a map as background as we want to figure out the location more accurately. 3/ Daily data infographics are not so clear. You can add the background to help understand. 4/ It is essential to have video functions in the group function. 5/ There are too many letters on the chat page. You can add a background color to group them.	1/ I prefer the blue color more because I like the blue sky and it will give us a clean feeling. 2/ The leaf idea is good because I think these elements can make us happy and it should be the parts of our daily life. 3/ Infographics are much easier to understand than the numbers. 4/ I like the group idea so we can support each other.

Table 1 Feedback from Usability Testing (continued)

Physical Product	1/ The gum can also be designed into different shapes and colors.	1/ The scan idea seems better because it is much easier for us to use (the sensor idea is a bit complex for me, a bit uncomfortable and seems to have more things to do). 2/ The leaf shape is beautiful, fancy and consistent with the app design. 3/ The gum idea interests me as it not only doesn't hurt but also make our life more colorful.

DESIGN REFINEMENT

The seniors' diabetes system includes a glucose meter scanner and an app GUM. The glucose meter scanner consists of the gum area and the scanning part. Seniors can see their glucose data on the app. They can see the suggestions & feedback according to their data. Moreover, they can join the diabetes group to support each other.

Figure 37 Scanner and Related App

Gum App Design

Logo Design

The chewing gum logo design was inspired by the tree shape, as the tree can give people a feeling of being healthy. The rising branch with some measures on it indicates that it is a glucose meter. The six leaves around the branch represent six people supporting each other, which is also in accordance with the group function in the app design.

Figure 38 Logo Design of the App

Updated Wireframe

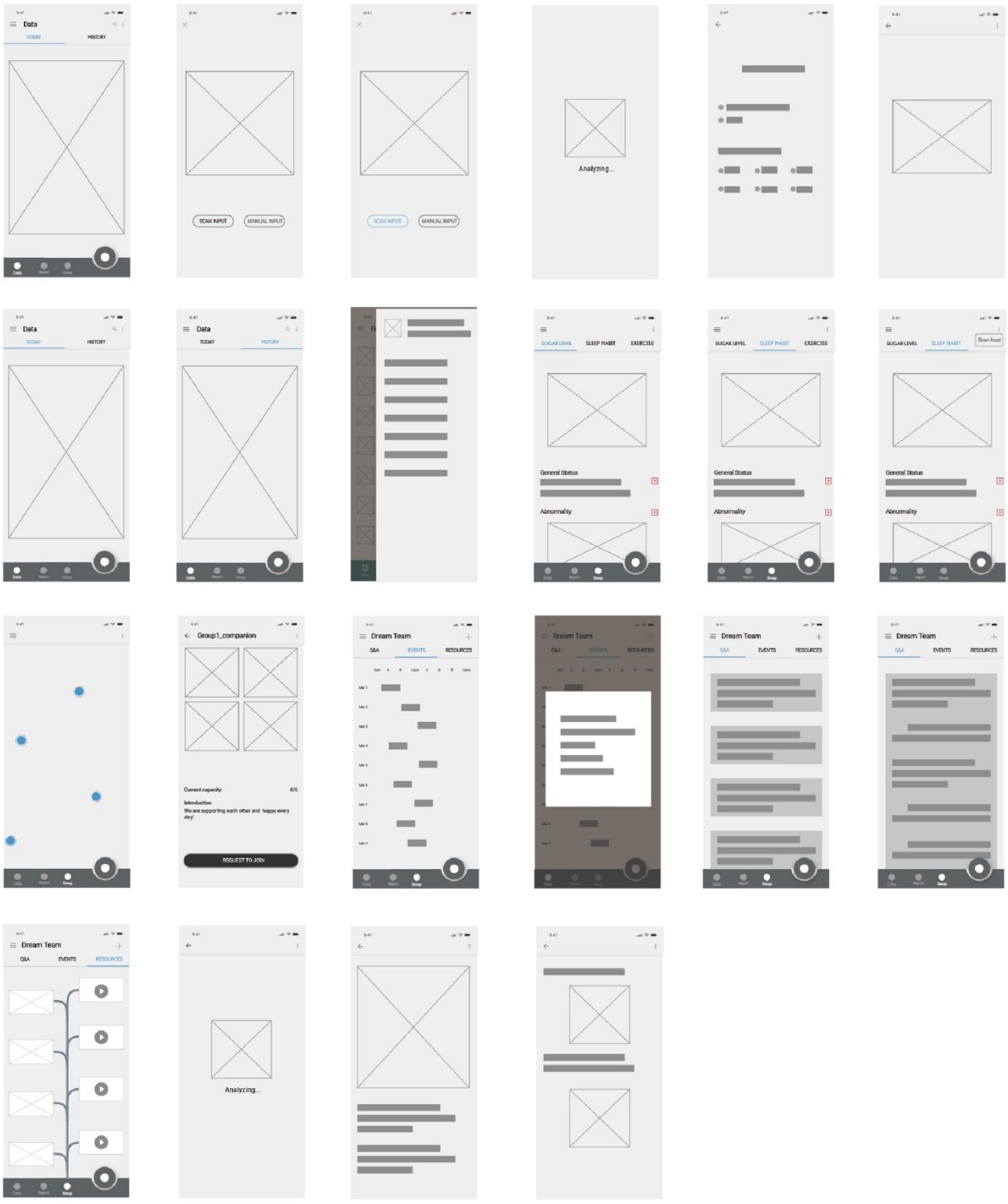


Figure 39 Updated Wireframe of the Gum App

Data Input Interface Design

Seniors can enter the data either by the Scan Input button or the Manual Input button (see Figure 41), meaning that even if seniors without the scanner can still use this app to get the data. When seniors choose the Scan Input button, then they need to use the scanner to get the data which will be sent to the app. Seniors can select the time period when they have tested, and they can also record additional information with the voice button.

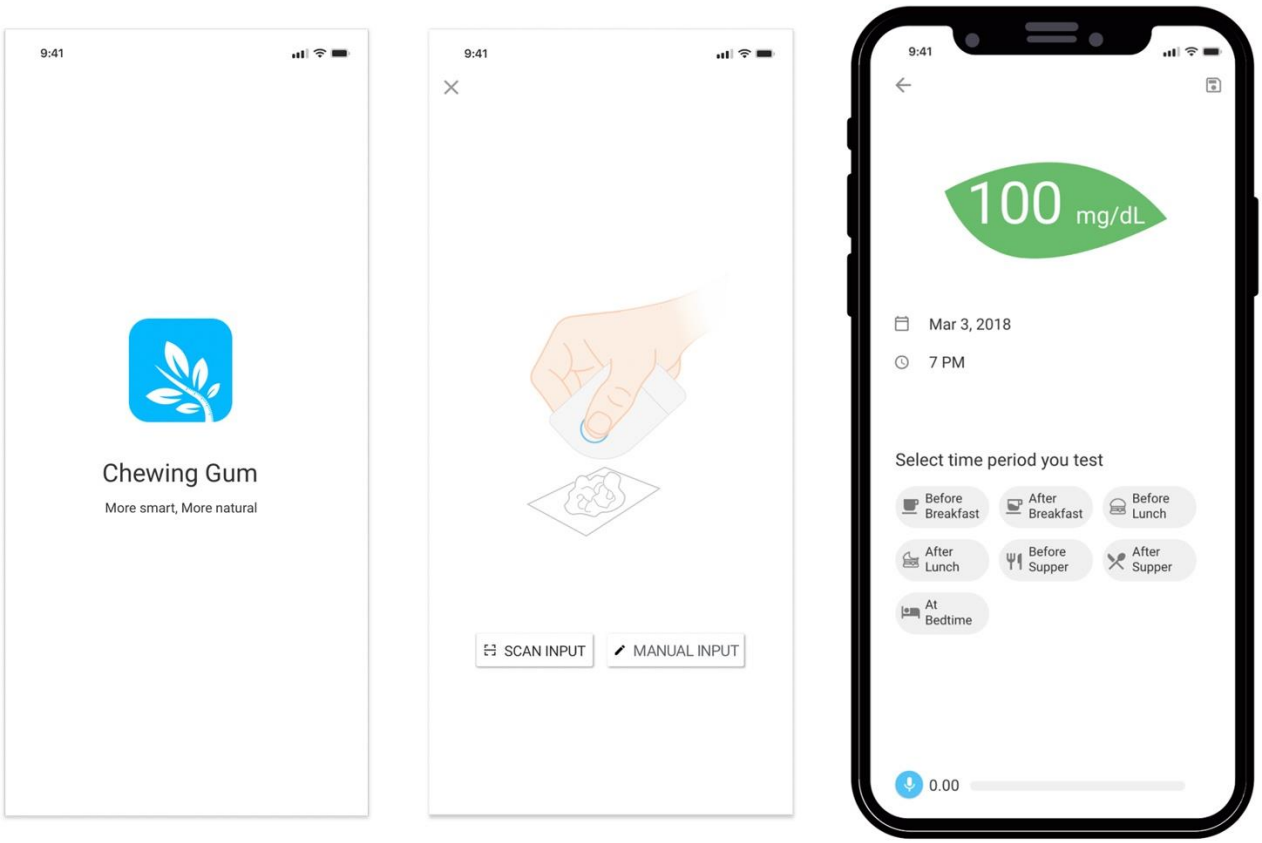


Figure 40 Data Input Interface Design

Data Interface

After seniors entered the glucose data and the related information, they will be directed to the daily data automatically (see Figure 42). There are four function buttons in the navigation bar at the bottom: data, report, group, and the data input buttons. The data function will show their daily and history data in an information visualization way. The report function will offer them the blood sugar level, their sleep habits and their exercise feedback according to their data. They

will get support including asking questions, studying, and doing exercise together via the group function. Pressing the floating button, they can choose to enter their glucose data.

Under the data function, they can see their daily and history data. By daily data visualization, they can know their testing time and the glucose level at that time. On the horizontal axis of the daily data visualization are breakfast, lunch, supper, and bedtime. On the vertical axis is the glucose level. The leaves show all of their glucose measuring data during a specific day with different colors indicating the different status. The green color means their glucose status is good, yellow means fine, and red means dangerous.

By history data visualization, seniors can know their glucose data in history. On the horizontal axis is the testing time and on the vertical axis shows the dates. Each branch shows the glucose data on a specific day. The leaves on each branch show all times of your glucose data during that day, and again, different colors mean different status.

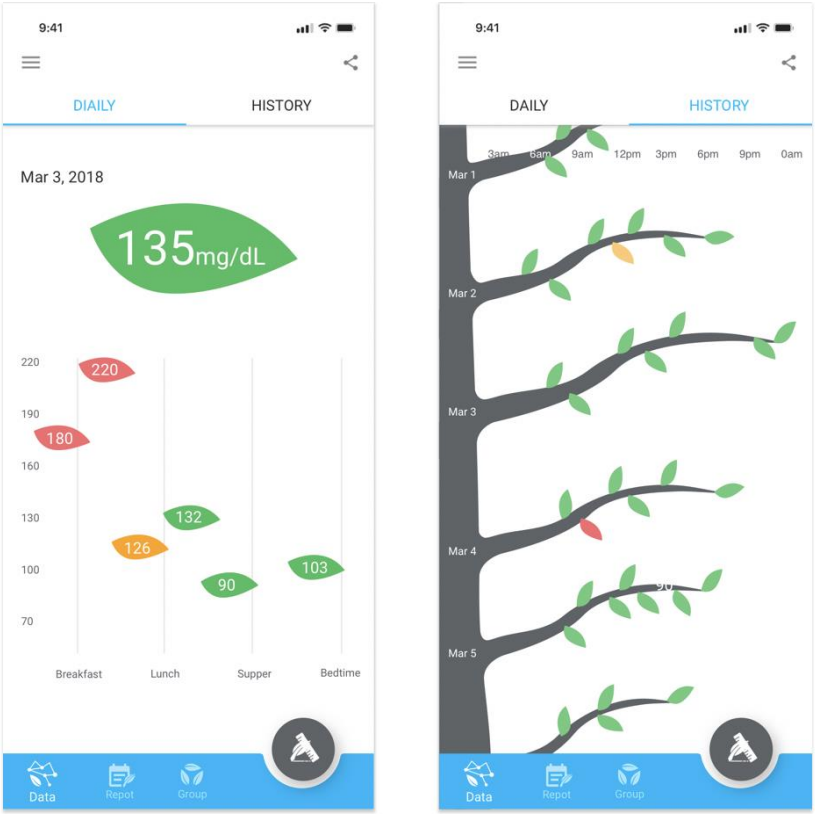


Figure 41 Data Interface

Data Report Function Interface

Data report can offer seniors suggestions according to their data. Seniors can know their general status and abnormalities based on their data. The app provides sugar level, sleep habits, and exercise reports. Sugar level, sleep habits, and exercising are the most critical factors seniors with diabetes need to consider in dealing with their diabetes. These reports can help them form a good habit and live a healthy life. Baby boomers are growing old in recent years. However, the number of doctors has not changed very much. So seniors have to wait for a long period of time for a doctor's appointment because of the imbalance between the number of seniors and doctors. This function can help seniors a lot and reduce the doctors' burden.

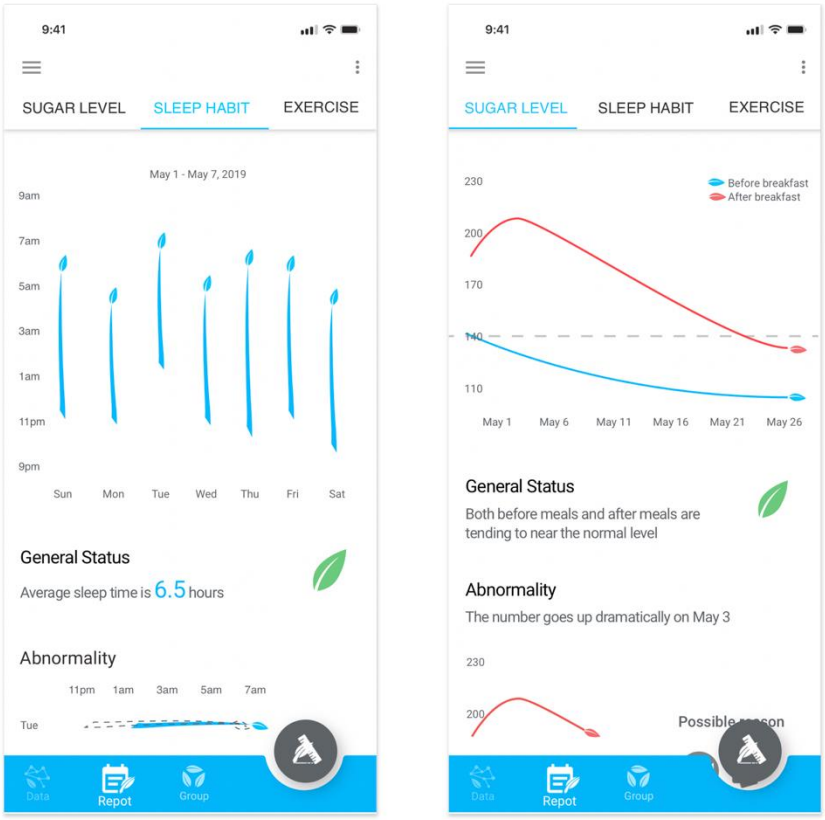


Figure 42 Data Report Interface

The first part of the sleep habit report (see Figure 43) is sleep time visualization which shows the sleep duration every day. Seniors can know their overall sleep status by the leaf color; This report can also find some abnormalities in their sleep habit. For example, it can find that they stay up late some nights and give them the right bedtime recommendations.

By sugar level report (see Figure 43), seniors can know the tendency of their weekly glucose data before/after breakfast. Compared with the target line, they can learn if their diabetes condition is getting better or not. The sugar level report can also tell them their general sugar level status and abnormalities. For example, it will show them the sugar level goes up dramatically and give them possible reasons and solutions.

Group Function Interfaces

Because most seniors live away from their children, and they are not so informed about the latest diabetes-related information and technology, it is necessary for them to form a support group. That is also why every month there is a diabetes education event in every town because they can always share their information and resources with each other during these diabetes events. However, it is not so convenient for seniors to move because of their physical status. Therefore, the group function can benefit them a lot. Each group has a doctor and the maximum number of members in each group is eight.

When seniors click the group function button, they can see all the diabetes groups around them (see Figure 44). The number of leaves indicates how many members are in each group. Seniors can decide to join the group based on the distance from them. When they click on each group, they can enter this group to see more details such as group introduction and member information. For member information, the number of leaves means how many members are in this group. The red color indicates the female gender; the blue color means the male gender, and the grey color indicates how many more people are allowed in the group.

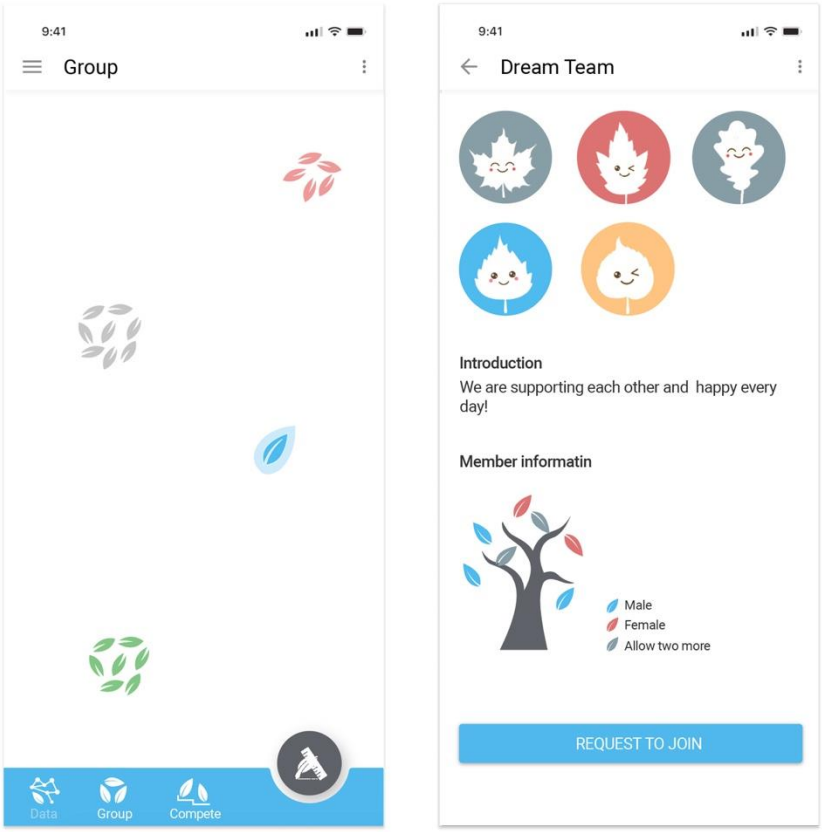


Figure 43 Group Interface Design

In the group, group members can ask questions, do exercises together and share the diabetes resources (see Figure 45). Figure 45 shows that seniors can click on the events button to see all the events and decide to join in or not. They can also click on each event to see more details such as the time, place, and the notices about the event.

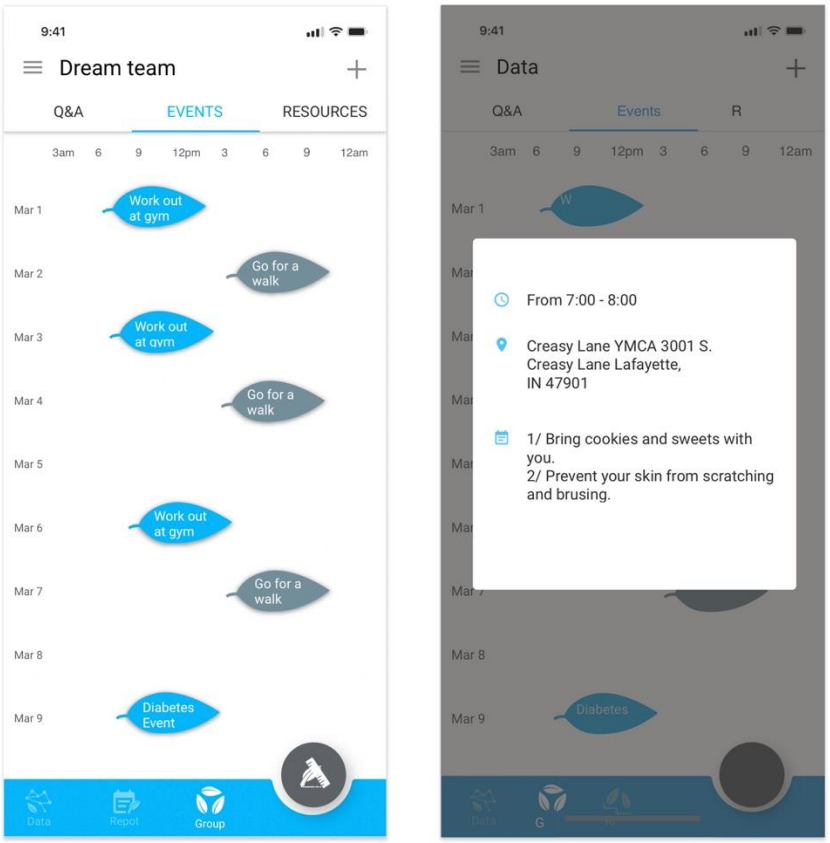


Figure 44 Events Interfaces

Figure 46 shows that members can share diabetes information, such as the diabetes videos, articles, and news. They can click on each card to see the content of every resource.

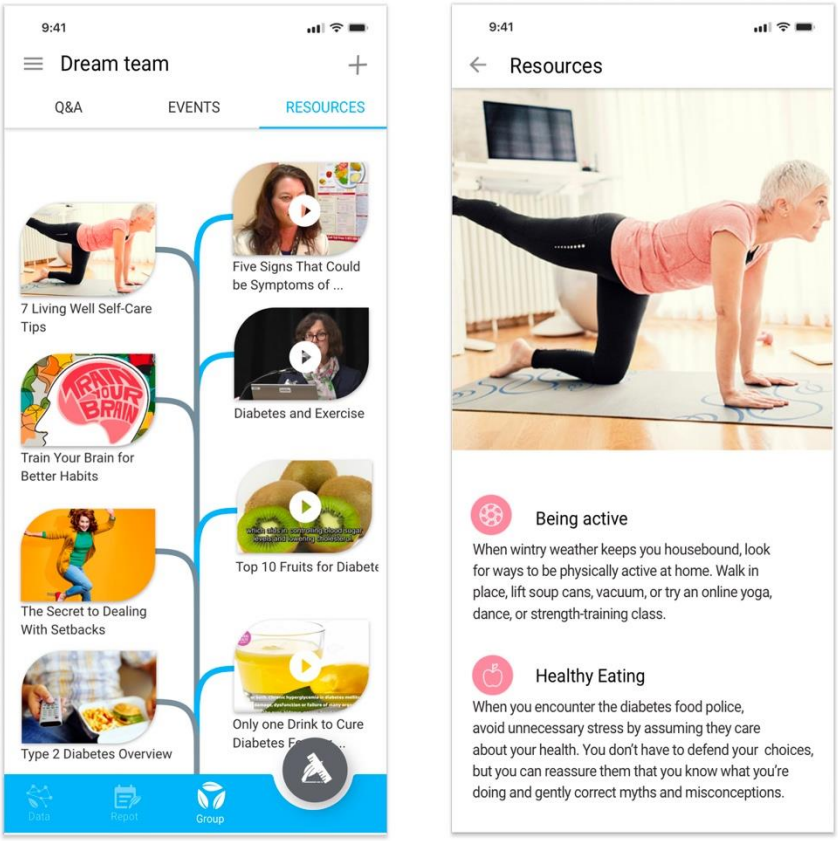


Figure 45 Resources Interfaces

Figure 47 shows that they can ask questions in the group. The doctor and the other members can answer the questions. They can also search and browse the previous questions.

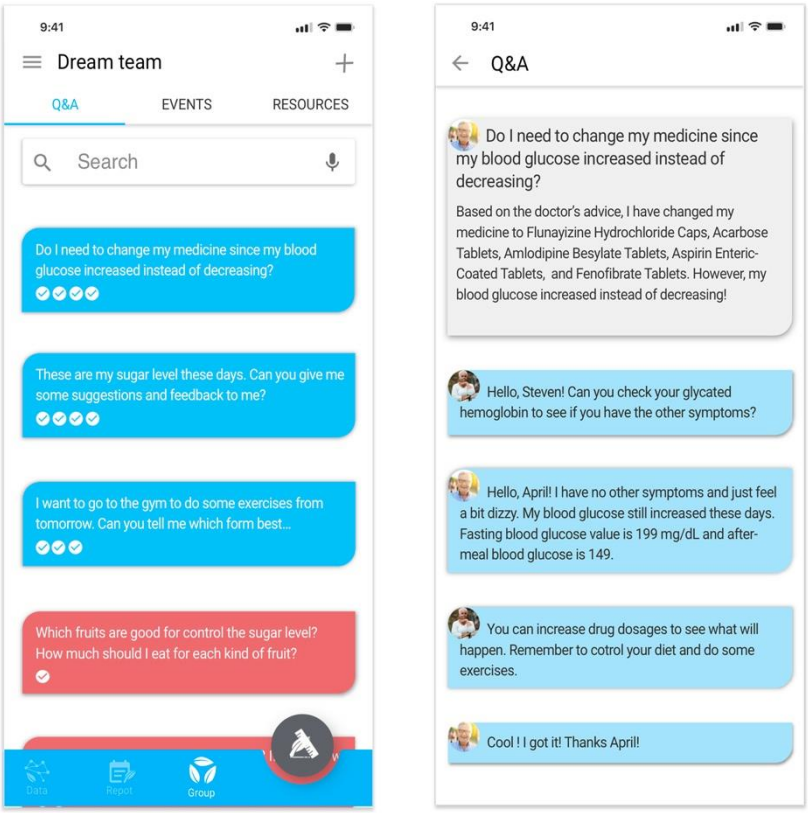


Figure 46 Q&A Interfaces

Scan Food Function Interfaces

Most seniors with diabetes dare not to take in any food with sugar in it because they do not know how much they are allowed to eat based on their situation. Overly restrictive eating patterns may cause undernutrition which is not beneficial to their health. In addition, eating food with some sugar can make their life happier.

Seniors can use this app to scan the food they want to eat, and the app can tell them how much they can take in based on their current data. After seniors scan the food, it will show how much sugar there is in the food, and it will show them the objects they familiar with in their daily lives (see Figure 48). Then they can know how much they can eat this food by the size of the object.

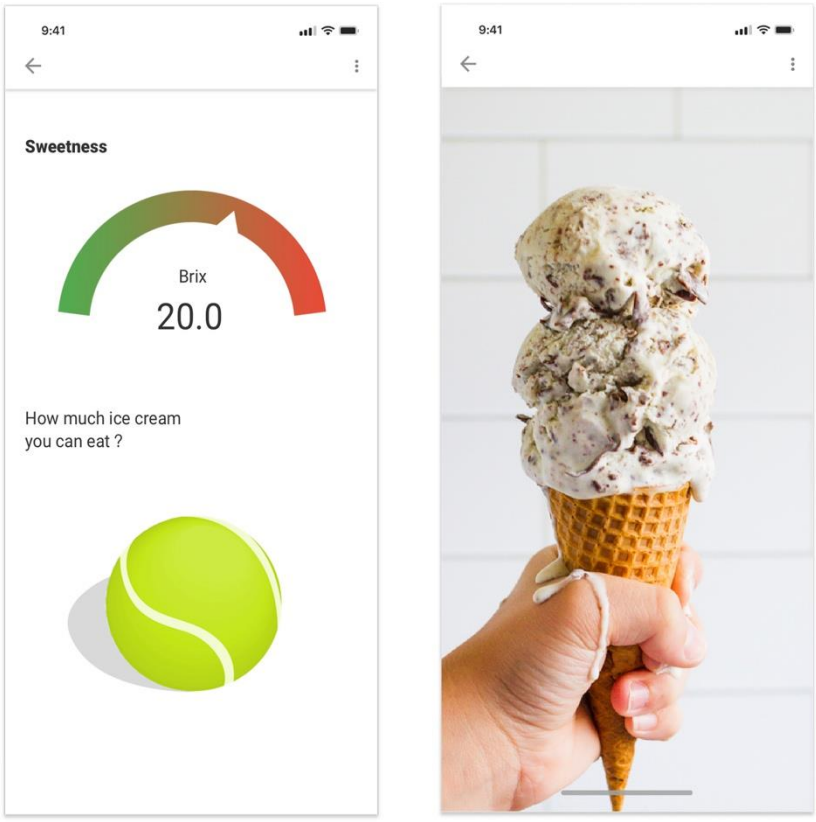


Figure 47 Scan Food Interfaces

Physical Product Design

Gum Scanner Design

The scanner, combined with the biological sensor technology, makes diabetic seniors' lives much easier. They will be glad to test their glucose level since they do not have to prick their fingers anymore. They will not feel awkward anymore to test their blood in public, as the scanner looks very modern. The whole testing process is also very relaxing and simple. The device is very portable as they do not have to carry multiple things (lancets, test strips, glucose meters) with them. Everyday testing becomes a very relaxing and happy thing!

As shown in Figure 49, the scanner consists of two parts: the gum area and the scanning part. The gum area can hold about eight pieces of gums. There is a big scan button on the product surface. The strong magnets on the lid and the gum area can make the lid close tightly.

Figure 48 Gum Scanner

The gum scanner can have different color choices (see Figure 50). Seniors can choose the scanner according to their color preference. Moreover, the form of the scanner is inspired by the leaf shape, which is consistent with the app design.

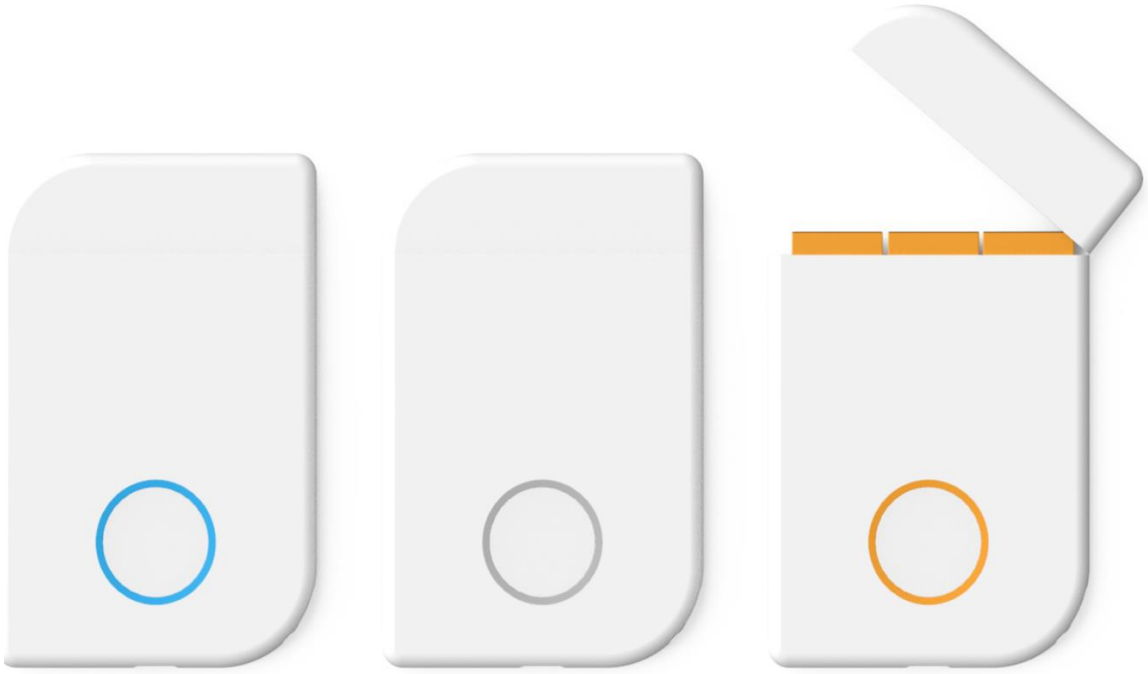


Figure 49 Gum Scanner Color Choice

The gums are also specifically designed: (1) The gum color and shape is consistent with the scanner. (2) There is no sugar in the gum.

Figure 50 No Sugar Gum

Figure 51 Gum Scanner Model

FINAL EVALUATION

I conducted usability testing in my final evaluation. Usability testing is the most common technique among evaluation methods. It can help the designer make sure that the design does not have usability problems and can bring seniors with diabetes a pleasant experience. Volunteering in the retirement village provided me with many resources for my design. There are four steps in my final evaluation, including creating a test plan, facilitating the test, analyzing the data, and creating the test report (see Figure 53).

Figure 52 Four Steps in Final Evaluation

Testing Plan

Testing Goals & Methods

The most critical factor designers need to consider is if the seniors' products are easy to use because of seniors' characteristics. So the first target I need to fulfill is to ensure that my product is easy to use and to figure out which part of my design is hard to understand and use. Also, for the physical product, I want to gain their opinions about shapes and colors. For the app design, my goal was to answer questions such as: are seniors satisfied with the interface design i.e. text size and color? How do they like all the functions? Moreover, I hoped that they could give me some constructive suggestions.

The testing methods I used in this phase included observation, questionnaires and interviews. I introduced the product first to let them know how to use the device and the app. Then they used

the product with my assistance. After their experience of the product, I helped them fill in the questionnaires and interviewed them. The testing equipment included the interactive prototype created by the principle software, the scanner models with the gum inside, a phone, questionnaires, a pen and a notebook.

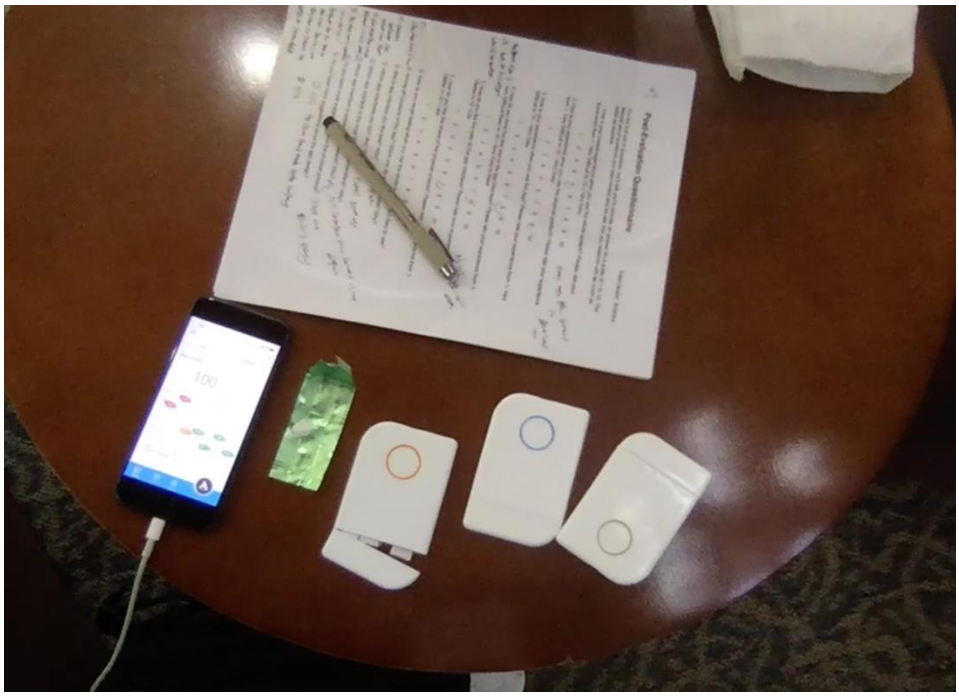


Figure 53 Testing Equipment

Testing Metrics

Testing metrics make usability testing more concrete and objective. Users can evaluate designs and offer suggestions & feedback according to these metrics. In my project, I used usability, visibility, affordance, aesthetic and minimalist design, feedback, and consistency principles to help seniors evaluate my design, combined Jakob Nielsen's ten usability heuristics for interface design (Nielsen, 1995) with Donald Norman's six design principles (Norman, 2013). Figure 55 shows the detailed information of the testing metrics used in my project.

Metrics	Detailed Description
User Control and Freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
Aesthetic & Minimalist	The physical embodiment of the system should be pleasing in its intended setting. The system should not contain information that is irrelevant or rarely needed.
Reduce Memory	The functions provided in the application reduce the memory or cognition load for the activities related to academic writing.
Consistency	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow software conventions.
Affordance	An affordance is a visual attribute of an object or a control that gives the user clues as to how the object or control can be used or operated. When the affordances of a physical object are perceptually obvious it is easy to know how to interact with it.
Ergonomics	Physical ergonomics is about the human body's responses to physical and physiological work demands. Repetitive strain injuries from repetition, vibration, force, and posture are the most common types of issues, and thus have design implications.
Readability	Readability consists of both legibility and understandability. Legibility depends on many factors, such as font size and typeface, color combinations, background texture, word style and computer pixel size. Understandability depends on things such as sentence length.
Visibility of System	The application should always keep users informed about what is going on, through appropriate feedback within reasonable time.
Flexibility and Efficiency of Use	Accelerators - unseen by the novice user - may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
Error Prevention	Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

Figure 54 Testing Metrics

Testing Users

If we want to understand how users behave and meanwhile can get quick insights, five participants are enough for our usability testing (Jakob Nielsen, 1993). I interviewed a total of five seniors during this stage, one of whom was from the diabetes education event in Lafayette

and four of whom were from the retirement village in West Lafayette Indiana where I worked as a volunteer.

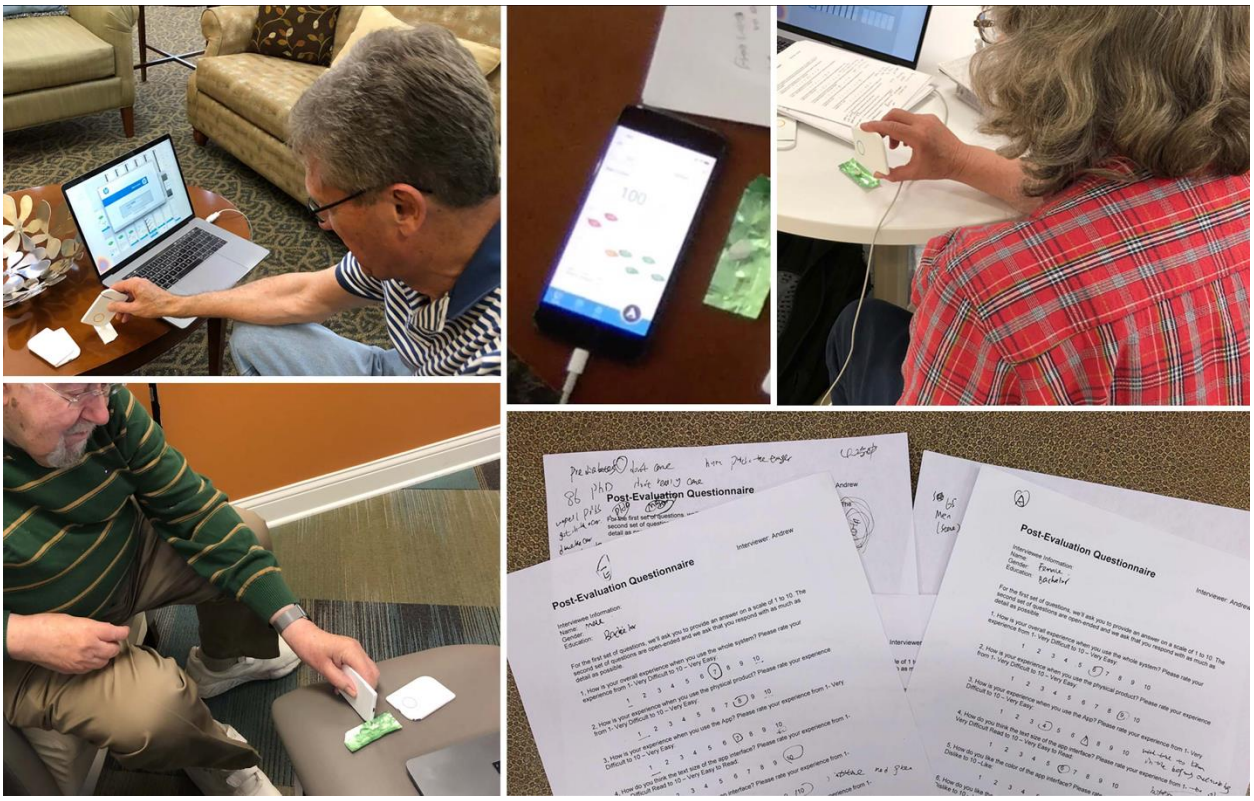


Figure 55 Testing Users

Three of them held a bachelor's degree, one had a master's degree, and the last one had a doctoral degree. The testing time was really uncontrollable since most of them had hearing problems, cognitive impairment, and memory loss. Table 2 shows detailed information of the evaluators including their necessary information and the evaluation time.

Table 2 Evaluators Information

Evaluator ID	**Basic Information**	**Duration of Evaluation**	**Date of Evaluation**
E1	Age: 70 Education: Bachelor's Gender: Female App Experience: Yes	15 mins	05/29/2019

Table 3 Evaluators Information (continued)

E2	Age: 65 Education: High School Gender: Male App Experience: No	20 mins	05/29/2019
E3	Age: 66 Education: Master's Gender: Male App Experience: Yes	20 mins	04/15/2019
E4	Age: 67 Education: Bachelor's Gender: Female App Experience: Yes	25 mins	06/03/2019
E5	Age: 90 Education: PhD Gender: Male App Experience: Little	50 mins	06/02/2019

Facilitate the Test

Four seniors were tested in the retirement village in West Lafayette while one was tested in the YMCA (Young Men's Christian Association) community room in Lafayette. The testing places were random and depended on where it was more convenient for the seniors to participate in my testing. It was not easy for them to move from one place to another because of their physical impairment. In my opinion, it is perfect since one of my design characteristics is that it is portable so seniors can easily use the product anywhere.

After they agreed to test I took out my phone with the interactive prototype in it and three scanner models with the gum models in it. Initially, I asked them some pre-testing questions to get their background information such as their education level and the app user experience since education background and app user experience are two factors that can affect their feelings about the product. The pre-testing questions were as follows:

1. Name:

2. Gender:

3. Education:

4. Have you used the app before? Yes/ No

Then, I introduced the product, explaining the design features and how to use the system. Since it is a totally new product and some seniors have cognitive and hearing impairment, I tried to introduce the product to them as slowly as possible until they fully understood. Also, to make sure they experienced both the app, the scanner and how these two interacted with each other, I let them try the product following these steps: (1) Click the scan input button on the app. (2) Use the scanner to scan the data. (3) Choose the time period for the test. (4) Check the data function including the daily data and history data. (5) Check the other functions like the report function and the group function. When they used the product, I observed them and took notes. In the meanwhile, I asked them some questions related to their behaviors to know their feelings and motivations. Finally, I asked them some post-testing questions to get their feedback on user experience. The post-testing questions were as follows:

1. How is your overall experience when you use the whole system? Please rate your experience from 1- Very Difficult to 10 – Very Easy:

1 2 3 4 5 6 7 8 9 10

2. How is your experience when you use the physical product? Please rate your experience from 1- Very Difficult to 10 – Very Easy:

1 2 3 4 5 6 7 8 9 10

3. How is your experience when you use the App? Please rate your experience from 1- Very Difficult to 10 – Very Easy:

1 2 3 4 5 6 7 8 9 10

4. How do you think the text size of the app interface? Please rate your experience from 1- Very Difficult Read to 10 – Very Easy to Read:

1 2 3 4 5 6 7 8 9 10

5. How do you like the color of the app interface? Please rate your experience from 1- Dislike to 10 –Like:

1 2 3 4 5 6 7 8 9 10

6. How do you like the shape of the physical product? Please rate your experience from 1- Dislike to 10 – Like:

1 2 3 4 5 6 7 8 9 10

7. How do you recall feeling when you use the whole system? Is it easy to use?

8. Among all the functions of the app? Which one do you like most? Why?

9. Which app interface you like best? Why?

10. Which app interfaces you don't like? Why?

11. Which app interface is the most difficult to understand? Why?

12. Which app interface is easiest to understand? Why?

13. Do you have more suggestions about the physical product?

14. Do you have more suggestions about the app design?

Data Analysis and Findings

To better understand the data, I drew a line chart for answers to the question one through question six of the post-evaluation questionnaire. As shown in Figure 57, all interviewers like the scanner design and they think this product is straightforward to use. However, some seniors are a bit confused with the app design.

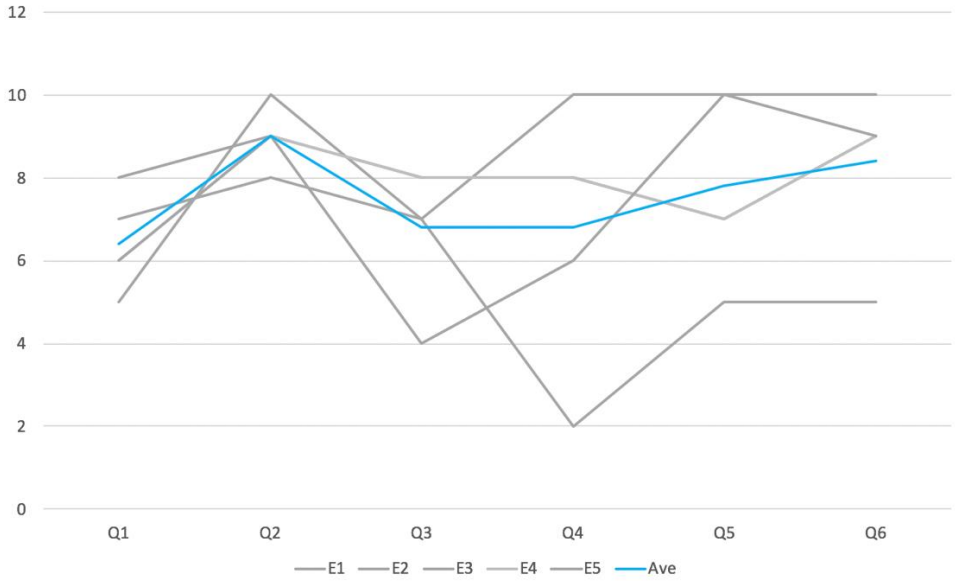


Figure 56 Average Value

I also found that educational background and the age had some effect on the value. As shown in Figure 58, two seniors are not so interested in the app. One senior is almost 90 years old, and he thinks it is too hard for him to learn how the app works. He also stated that seniors at this age would not care about their diabetes anymore. The other senior who has a high school degree said she had not used the app before, so she showed little interest in it.

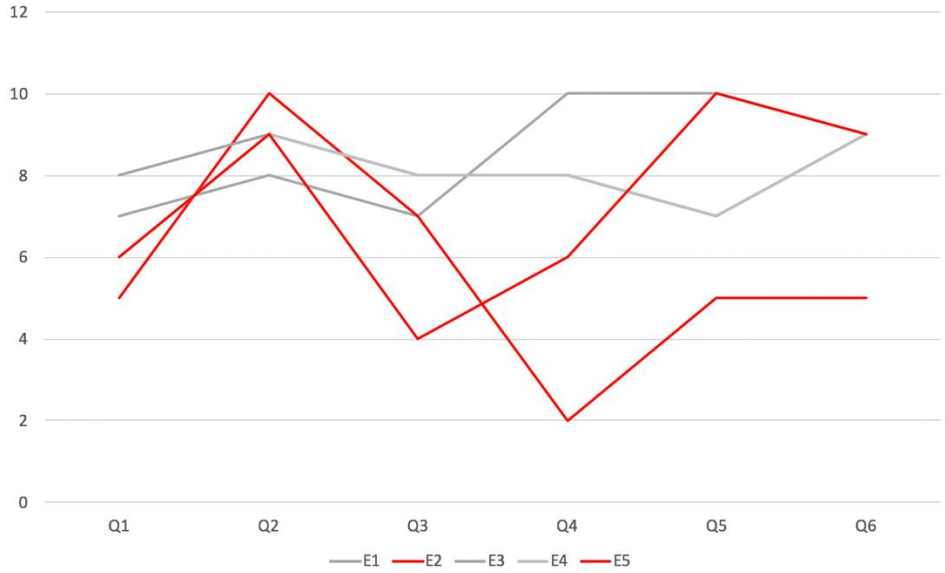


Figure 57 Low Value on Digital Product

During the usability testing, seniors provided me with a lot of feedback which I analyzed and grouped them in Table 2 below. Some findings are really impressive to me, and I want to introduce here. The first is the relationship between seniors and technology. During the interview, all participants mentioned that they liked the scanner product. Most seniors were very fond of the whole design system including the physical product and the app, wanting to spend time to try them. They think the technology makes their lives much more manageable. However, there is an exception for seniors above 90 years old. Seniors over 90 years old showed little interest in the app because of their functional and cognitive status. Most of them didn't care about their diabetes anymore and just wanted to enjoy the remaining days. When I tried to find interviewees in the retirement village, seniors who were over 90 showed little interest in the interview. However, I tried to interview two seniors around 90 years old, and one of them finally gave up. The 90-year-old Purdue professor with a Ph.D. degree was delighted to join the interview, but still showed little interest in the app design. In his opinion, although he has

diabetes, he does not want to care about it anymore. He only tests his blood one or two times a month. Therefore, in my opinion, my target users for this product could be seniors aged 65 to 85.

Another interesting finding is that those seniors are fond of original and interesting data presenting ways. Whether seniors like the information visualization way to show the data or not is a topic I doubt about these years. All of them, except for the one aged 90, liked the data visualization in my app design. They think that showing data with information visualization techniques can help them understand the data better. Table 3 shows the positive and negative feedbacks for both app design and scanner design.

Table 4 Feedback from Usability Testing

	Negative Feedbacks	**Positive Feedbacks**
App	1/ The caption and overline text size is a bit small. 2/ The information on interfaces under the report function are a bit overwhelmed. 3/ You can also show the monthly data under the history data button.	1/ Using the tree idea to visualize the history data helps them easier to understand the data. 2/ Present the data with color can help them understand the data. 3/ All interfaces are simple and once they learned, they could get used to them. 4/ You can add the medication reminder function because I always forget to take medicine with me.
Physical Product	1/ The scanner can be a bit larger so that they will not lose it or it can be designed to stick on the back of the phone.	1/ The design is very comprehensive and attractive. 2/ The scanner is very portable, and seniors can easily bring it somewhere.

Directions for Future Work

As I have mentioned before, it seems like seniors over 90 years old do not care about their diabetes condition and new technologies anymore. Most of them do not want to try the apps. However, seniors aged 65-85 are very interested in new technology and they believe that new technology can bring benefits to their life. They want to try the new technology and think the

technology is accessible for them to use once they get used to it. So for my project, the primary target users can be seniors aged 65 to 85. Seniors over 85 years old can still use the data function on my app and ignore the other functions if they do not want to use them. Another option is to design another version of the app for seniors aged 85 and over. The interfaces under the report function can also be improved since some seniors think these interfaces are a bit overwhelming. I can use more graphs to show this information instead of using text.

According to the American Association of Retired Persons (AARP), almost sixty-five percent of seniors owned the smartphone in 2017, and more than seventy percent of seniors will have the smartphones in 2020 at this increasing rate. With more seniors embracing the technology at an unprecedented rate, I believe my design will have a massive potential in the market of seniors with diabetes.

CONCLUSION

This project aims to adopt the advanced technologies, based on seniors' characteristics, to build a smart system for seniors with diabetes. With this smart system, seniors can test their blood relaxedly and regularly without any hurt or pain. With a nicely crafted product, they will not feel awkward to test the blood in public anymore. Daily blood testing becomes a relaxing experience. In addition, this system can show their data in a more clear and interesting way. The smart system can give seniors with diabetes feedback and suggestions based on their glucose data. Moreover, with the supporting group function, seniors can ask diabetes expert questions in the group, share the information and do exercises together. In a word, the diabetes system is an excellent companion to seniors with diabetes. In this project, I also tried to explore and successfully embeded new technologies into seniors' products. I have found out a way of how to narrow the gap between seniors and technology and using technology to make their life easier and happier.

Through literature review, I learned the disease in depth and also knew the diabetes situation in the senior group. Seniors have their own characteristics so the diabetes treatment is different from the general group. Seniors' diabetes condition is much more complicated than the young people, which makes them harder to manage diabetes. Meanwhile, I have found few research about the product designed specifically for seniors with diabetes which means my design can be unique to seniors. Through literature review I learned a lot about seniors' characteristics such as the functional status, their cognitive impairment, which will make my design more suitable to seniors' needs and wishes. Literature review equipped me with solid knowledge for later user research, case study and design. As we all know technology can make our lives easier and better, I also studied the recent diabetes technologies and the new technologies that have potential to be used in seniors' diabetes products, expecting to find a way out among technologies to help seniors manage their diabetes.

A series of interviews were conducted during the design process. I have attended the diabetes education event in Lafayette several times which is the only resource they can get in the town. There I found that although it is not so convenient for some seniors to move around, they still

want to come here since they can ask the experts several questions, they can support each other and share information. To better understand seniors' conditions, wishes and needs, I volunteered in the retirement village in West Lafayette every week. There I learned that some seniors have pretty poor memory and functional impairment. I know that they feel lonely and isolated since they always live far away from their children. I learned that their everyday life is very tedious since they have spare time all the time. Except for interacting with seniors, I also interviewed relevant people like their children, the caregivers to know more about the seniors' situation from a different perspective. I learned that some seniors need to take several medications and it is hard for them to manage these medications. One of my interviewers buys the medicine for his mother and drives to his mother's home to help her put the medicines in different cases. I learned that the vision problem makes seniors challenging to visit doctors. I learned from a nurse that seniors need a group function on the app to support each other because most of their children care little about them.

By analyzing the peer products, I learned what similar products look like and got inspiration from them. I found the problems in the current products and tried to improve those parts in my own product design. More importantly, I found that there were no specific diabetes products designed for the senior group. There will be some challenges when seniors use them: the small text size on some app makes seniors hard to read, too much information on some interfaces will make them overwhelmed and a lot of steps & interactions will make them confused. To better experience the diabetes products in the market I bought two diabetes meters to test my blood and kept dairies every day. I found the biggest challenge of the diabetes product is that they need to prick their fingers six times every day which is painful and horrible. I found these meters are too complicated for seniors to use. I also found these products are not portable because seniors need to bring many things include the meter, the test strip, lancing device, and lancet with them.

Although many problems have been found during the research, in this project I focused on three problems: (1) There is a need for more supporting information. (2) Testing the blood glucose level is not comfortable. (3) Data can be used to treat diabetes better. After drawing a bunch of sketches to explore the idea, HTA chart, wireframe, low-fidelity prototype, mockups were developed in the first design iteration. Then I brought the mockups to conduct usability testing

among seniors. Based on their feedback, I refined the design. Finally, the interactive app prototype & final models were used in the usability testing and seniors were satisfied with the product system.

Three problems have been solved in this project:

(1) There is a need for more supporting information. By the report function on this app, the system can give them feedback according to their data to help them manage diabetes. For example, the system can tell them their general status so that they will know their diabetes conditions at any time. The system can also find abnormalities in the data collected and provide possible answers. With grouping function, seniors can choose to join the diabetes groups around them. In the group, they can ask the diabetes expert questions, exercise together, and can share diabetes information. With this product system, seniors can manage more diabetes problems by themselves.

(2) Testing the blood glucose level is not comfortable. Every people with diabetes is afraid to prick their fingers to test the blood because the experience is painful. Plus, it always happens that they need to try several times to prick their fingers successfully. With this product, seniors with diabetes do not need to prick their fingers anymore. Through chewing and testing gums, blood testing becomes a relaxing experience every day.

(3) Data can be used to treat diabetes better. Making good use of data and using the information visualization way to show data can help seniors manage their diabetes. For example, using the leaves and colors to visualize the data can help them better know their daily & history data. Telling them the overall status and providing them the possible reasons for abnormalities by the report function can reduce their times to visit the doctors to ask questions. Scanning the food to decide how much they can eat can make them eat more healthily.

Although seniors are very satisfied with the product-system design, I still found some potentials to improve during the usability testing. Seniors aged 65-85 are very interested in the new technology and they believe the new technology can bring many benefits to their life. However, for seniors over 90 years old, they do not care too much about their diabetes anymore and show little interest in the new technology. Therefore, the target user could be seniors ages 65-85. For

seniors over 85 years old, they can just use this app's data function if they feel overwhelmed. I can also design a version for seniors over 85 years old. In the future, I can also consider more about this production system such as the brand design and business model canvas to help it become a successful product in the market.

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APPENDIX. CONTEXUAL INQUIRY SURVEY

The interview questions being asked are listed below:

Interviewee Information:
Name:
Gender:
Education:

For the first set of questions, we'll ask you to provide an answer on a scale of 1 to 10. The second set of questions are open-ended and we ask that you respond with as much as detail as possible.

1, How is your overall experience when you use the whole system? Please rate your experience from 1- Very Difficult to 10 – Very Easy:

1 2 3 4 5 6 7 8 9 10

2, How is your experience when you use the physical product? Please rate your experience from 1- Very Difficult to 10 – Very Easy:

1 2 3 4 5 6 7 8 9 10

3, How is your experience when you use the App? Please rate your experience from 1- Very Difficult to 10 – Very Easy:

1 2 3 4 5 6 7 8 9 10

4, How do you think the text size of the app interface? Please rate your experience from 1- Very Difficult Read to 10 – Very Easy to Read:

1 2 3 4 5 6 7 8 9 10

5, How do you like the color of the app interface? Please rate your experience from 1- Dislike to 10 –Like:

1 2 3 4 5 6 7 8 9 10

6, How do you like the shape of the physical product? Please rate your experience from 1- Dislike to 10 – Like:

1 2 3 4 5 6 7 8 9 10

Q: How do you recall feeling when you use the whole system? Is it easy to use?

Q: Among all the functions of the app? Which one do you like most? Why?

Q: Which app interface you like best? Why?

Q: Which app interfaces you don’t like? Why?

Q: Which app interface is the most difficult to understand? Why?

Q: Which app interface is easiest to understand? Why?

Q: Do you have more suggestions about the physical product?

Q: Do you have more suggestions about the app design?