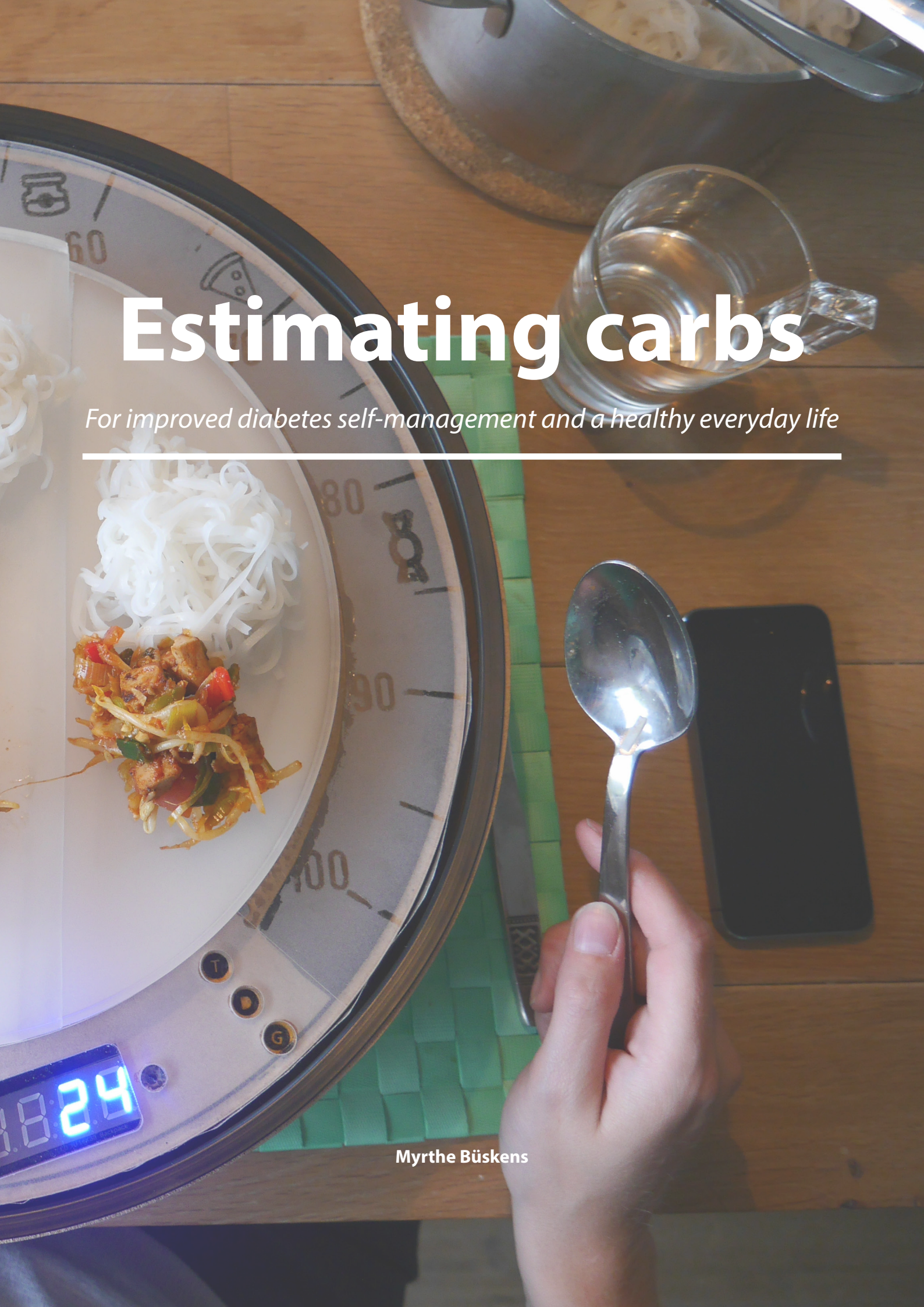


Estimating carbs

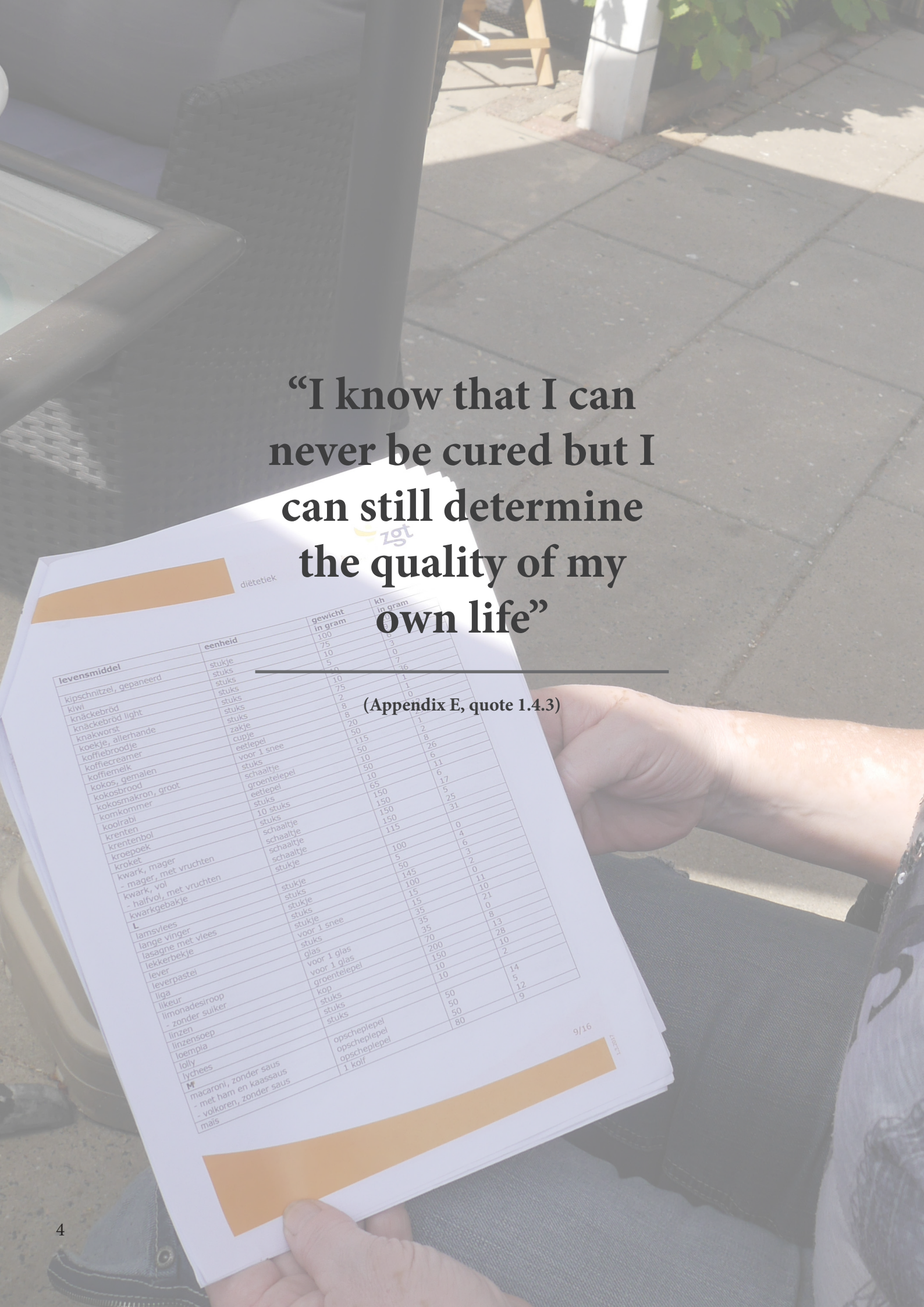
For improved diabetes self-management and a healthy everyday life

Myrthe Büskens

Estimating carbs

For improved diabetes self-management and a healthy everyday life

Myrthe Büskens



“I know that I can never be cured but I can still determine the quality of my own life”

(Appendix E, quote 1.4.3)

COLOPHON

Master thesis
Estimating carbs: for improved diabetes self-management

Master Design for Interaction
Department of Industrial Design Engineering
Technical University of Delft
23rd of August, 2017
Myrthe Büskens

Graduation committee
Dr. M. Sonneveld
Dr. F. Sleeswijk Visser
Dr. G Bergman
Msc. T. Hofker

Preface

Before you lies the Graduation report of my Graduation Project: Estimating Carbs: for improved diabetes self-management and a healthy everyday life. The assignment was collaborated on together with Roche Diabetes Care and the faculty of Industrial Design Engineering Delft. For me it proved to be an opportunity to apply my skills and knowledge build in both Eindhoven and Delft for a company new to design within the medical context; plenty of challenges! My personal drive for this project is that I believe design can play an important part in building the healthcare of the future. Where designers can not take away the source of being sick, they can build the world around the disease in the most comfortable and positive way. We just first have to discover what people need or want when and where.

This project evolved around the concept of counting carbohydrates, an important part of diabetes self-management for people with an intensive insulin therapy. I have found it challenging and inspiring to visit the homes of people with diabetes and research different people in this therapy. It was thrilling to try to get to know the people who are using the products of Roche DC and what they actually do or do not do with the products and why. My personal objective was to discover where design could become the needed extra support, the extra push that could help people in the right direction within their therapy. I think what my research shows is that there are many opportunities for design to improve the lives and experiences of people with diabetes. It is a tough disease, influencing your life every minute of the day, whether you are aware of it or not. It is therefore not diabetes that people have to manage but it is their life with diabetes that they have to learn to manage. This for me is the most important part a designer can prove his value: how can we support people in managing diabetes within their personal life, with all its disruptions that life brings.

What I enjoyed most about this project was involving 27 people with diabetes and learning from their stories. This has created all richness of this project and left me to create direction and solutions. The end result is not final but it is I believe a step into the right direction where people with diabetes get offered support not only for their disease but for dealing with the disease in their own pace, with their own approach and in their everyday life. When combining the worlds of technology, psychology and creativity, who knows what other solutions can be found to improve the everyday life of people with diabetes one step at a time.

I hope you enjoy your reading.

Myrthe Büskens
Delft, 9th of august 2017

Executive summary

People with diabetes who are treated with an intensive insulin treatment have to make many changes to their life. They have to start watching their exercise, their diet and they have to keep diabetes under control through regular monitoring and insulin injections. This diabetes self-management asks a lot of someone, both cognitively as emotionally, in his everyday life.

The success of an intensive insulin treatment is dependent on the ability of someone to determine his carbohydrate intake: when you know how much carbohydrates you eat, you know how much insulin you have to inject. However, determining your carbohydrate intake is experienced as ambiguous, complex and confusing. This assignment focuses on people in an intensive insulin treatment who have to enter the grams of carbohydrates that they are about to eat into a blood glucose meter.

The project has been executed following an iterative process consisting of four design-research cycles. Design methods were used such as sensitizing exercises, pictures of home, 5-day in-home exercises, paper prototyping and user-testing with a working prototype. Through each cycle, a stronger focus in research was found to answer the question how people with diabetes could be supported in determining their carb intake. People receive a training in counting carbs but when they come they are advised to try things and discover what works for them, this caused insecurities and fall-back into previous behavior. Research of the different cycles showed that people prefer to estimate their carb intake over calculating it because that takes up a lot of time and there will always be times when you have to make an estimation e.g. in a restaurant. Also, in practice people often determine their carb intake when they have served their plate at dinner rather than when the ingredients are still separate before cooking. Determining the carb content of mixed meals is experienced as extra difficult. However, the two biggest issues mentioned is struggling with finding trustworthy information on carb ratios of products and converting such ratios to personal portions.

The goal of this assignment is to design a product that trains people with diabetes in intensive insulin therapy in estimating their carb intake by supporting them with exercises and insights so they can learn to intuitively apply their knowledge and skills. The final design proposal is the Training Scale: a plate that asks the user to estimate the carb content of the food placed on the plate and that will calculate the right amount and feedback whether the estimation is accurate or not. Rather than supplying people with tools and technology that can determine their carb intake for them, people are asked to think along to built the skills and knowledge that will teach them to estimate their intake confidently, flexibly and independently. Named added values for the Training Scale are that it raises awareness and knowledge, that it offers certainty through accuracy and that it is relieving people of worries about complex calculations.

The idea behind the Training Scale is that people eventually become independent of it over time. This however, could not be tested within the time limits of this project and therefore remains an interesting subject for future research. The user scenario for the Training Scale is also not entirely fixed upon. Ideally, the plate could be designed so everyone can use his own plate on it. Future research could point out the possibilities to meet this requirement.

Table of contents

1. Introduction

Diabetes is a chronic, incurable disease in which the blood glucose levels are excessively elevated because the body can not use or can not produce the hormone insulin. It belongs to one of the largest global health emergencies of this century (International Diabetes Federation, 2015) but has the tendency to be slightly underestimated by the public. Firstly, because diabetes can cause dire complications in many parts of the body but is not always seen as the source of these problems. Secondly, the consequences of diabetes are difficult to comprehend or recognize for people who do not have diabetes because they take place in every day life. People who suffer from diabetes do not undergo a period in which they are treated or cured, they have to manage their disease every day for the rest of their lives. When diabetes self-management is done properly, people with diabetes do not look sick to the outside world but this does not take away the worries and responsiblities that come together with diabetes self-management. This self-management is key for current diabetes treatment but it asks for knowledge, acceptance, willingness, motivation and endurance of the person with diabetes (Arends et al., 2009, p.63). This graduation assignment evolves around the concept of diabetes self-management. Together with the company Roche Diabetes Care the assignment was formulated around an existing therapy support program that they offer.

Different treatments

People with diabetes can be put on different treatment plans, depending on the physical and mental situation of a person. Different treaments vary from lifestyle changes, oral medication, conventional insulin therapy and intensive insulin therapy. The last, Intensive Insulin Therapy (IIT), such as Multiple Daily Insulin (MDI) and Flexible Insulin Therapy (FIT), is the most radical because it asks a lot of people in having not only to manage their own disease but also to change their lifestyle. They should start a healthy diet by eating less fast carbs, do regular physical exercise and control and manage their blood glucose levels at all times. They have to check their blood glucose levels and administer insulin to themselves based on the glucose levels of that current moment, preferably 4 times a day. In this way the blood glucose levels can be kept within the healthy ranges. If the blood glucose levels are too high (hyperglycemia) or too low (hypoglycemia) major consequences are involved. Especially hypoglycemia is feared by most because it can put someone in a coma with ultimately death as a worst case consequence. Checking one's blood glucose levels is still done manually by the majority, meaning that a pricking pen is used to pierce the finger so a small drop of blood can be applied on a disposable strip that is connected to a meter. Insulin is injected via a pen or pump.

BolusCal

One of the therapies that Roche Diabetes Care offers in the Netherlands is called BolusCal. The name is a merge of insulin bolus and calculating the amount of carbohydrates in a meal. Bolus insulin is the amount of insulin that someone injects to account for the glucose taken in through food. This means that the amount of insulin of a bolus is variable, depending on the size of the meal but also on the current blood glucose levels, physical exercise and for example illness. Injecting a bolus is part of the basal-bolus insulin therapy, where basal insulin is injected once every 24 hours to account for a stable blood glucose level during fasting periods and where bolus insulin is injected with every meal. BolusCal is a structured education program offered to people who need multiple injections of bolus insulin every day, so who are in Flexible Insulin Therapy (FIT). Those injections should vary based on what someone eats, how he feels and what he does. However, calculating the amount of bolus insulin manually is difficult since many factors have to be considered and affect each other. People who enter the BolusCal program receive a blood glucose meter, the Accu-Check Aviva Expert, that uses an algorithm to calculate the bolus for someone with diabetes, in this way offering an easier, flexible and more accurate way to treat someone in FIT.

The BolusCal program consists of new tools and accompanying trainings. The tools include the meter with the bolus calculator, a pricking pen and test strips. The trainings are provided by Roche Diabetes Care but executed and organised by dieticians and diabetes

nurses of hospitals. In total 2 trainings of 4 hours are given that cover the use and functions of the meter and the basics of counting carbohydrates. These trainings are mandatory for everyone who wants to use the meter.

The general advice for using the meter is to use it for every meal, before you go to bed and if you feel that your blood sugar might be too high or too low. In practice, on a normal day this means most of the times that you ask for a bolus advice 4 times a day. Every time the meter is asked for a bolus advice the amount of carbs that are going to be eaten have to be entered in the meter. This means that the user has to be able to determine how many carbs his meal contains.

Challenges of BolusCal

For people with diabetes type1, there are about 600 tasks, both cognitive and behavioral components, that they have to learn and master between being diagnosed with the disease and being able to self-manage diabetes independently (Coffen, 2009). About 50 of these 600 tasks have to do with carbs; skills and knowledge related. It proves the importance of knowledge and skills with carbs for self management. Everyone who starts the BolusCal program has to start with counting their carbohydrate intake. The consequence is that they have to think about their carbohydrate intake with everything they eat to determine whether they have to ask for a bolus advice or not. This requires knowledge of food and nutrition and time investment to learn about personal carb intake. The BolusCal program is now still dependent on the input of the user. People have to determine how many carbs they eat and enter this in the bolus calculator. If the user cannot do this accurately than the advice of the meter will not be accurate either. The accuracy of the required insulin dosis is therefore highly dependent on the accuracy of the carb estimation and therefore of the skill of someone with diabetes to make that estimation.

Next to the cognitive challenge of learning to estimate carbohydrates the therapy also means a shift in behavior. If someone has been handling his diabetes for 10 or 20 years in a different therapy, it will be a challenge for this person to change his ways to the BolusCal program. Even though the new therapy might mean that the blood glucose levels will improve, people might not feel this as an improvement because they have to change, give things up or put much more time and effort into their diabetes management. They experience the new program as though diabetes is taking control over their lifes. This shift causes people to feel the responsibility of diabetes more than before and can therefore cause insecurities.

Design Assignment

This assignment focuses on people who are eligible for FIT and who have to start determining their carbs for their BolusCal therapy. No distinction is made between type 1 and type 2 diabetes, or between pen and pump therapy. Whether someone is eligible or not is determined by a healthcare professional. Factors such as willingness of someone to change, mental state (e.g. good working memory) and critical blood glucose levels are factors that are taken into account before a healthcare professional determines whether someone is fit for the therapy or not (dr. R. Bianchi, personal communication, march, 6, 2017).

The assignment incorporates investigating the existing program and the reactions of the participants to find ways to support people specifically in counting carbs and in managing diabetes independently after they have followed the BolusCal training sessions.

The assignment has the goal to enable people with diabetes in FIT therapy to manage their diabetes independently, flexibly and confidently by investigating needs for support in determining carbohydrate intake. It consists of two parts: firstly, investigating the current program and finding insecurities of people with diabetes and secondly, supporting people in the ability to count carbohydrates simply.

Main design question
How can people with diabetes be supported in determining their carbohydrate intake in an independent, flexible and confident way?

Research questions:
1. How do people who are counting carbs after having participated in the BolusCal program look back at their first weeks after the training?

2. How do people approach counting carbohydrates in the current program and where do inaccuracies and insecurities arise?

3. What solutions could supoprt people in determining the carb content?

2. Gap and significance

This project builds on previously executed research (2015) for Global Roche Diabetes Care by Froukje Sleeswijk Visser and Wouter van der Hoog who together form Design Research Rotterdam. The MDI Experience Research Study presented Roche DC with deep customer insights and a development of future value propositions. By researching the experiences of diabetes in everyday life of people in MDI therapy, growth opportunities in the MDI therapy could be identified.

Main insights taken from the MDI Experience Research Study are regarding the impact of diabetes on people's everyday life, that it is major and that it is slightly underestimated. Especially the emotional needs are currently unmet. People feel stress and anxiety when thinking about the long-term health consequences that diabetes might have. Stress is also increased by the insecurities that are involved in diabetes: insecurities of determining the amount of insulin incorrectly by for example counting the carbs incorrectly or insecurities caused by a lack of knowledge.

There is great value in having the freedom in choosing what to eat. Something that some people feel they lose when being diagnosed with diabetes or when starting an intensive insulin therapy. This bad image of diabetes therapies is a first mental setback that can influence people's perseverence in the therapy. The study also describes a difference in attitude between people with type 1 diabetes and type 2 diabetes. People with type 1 diabetes have to change their life from the first moment of diagnosis. Often for type 2 diabetes, the disease develops gradually causing some people to feel the urgency in changing their lifestyle only after a medical episode (stroke, diabetes feet, failing eyesight etc.)

The insights show that there is an opportunity in creating more user comfort (cognitively and emotionally) by minimizing risks, offering education and providing extra support. More research is needed to understand how this support could be most effective and in what form this support should be given to fit the user and his context. Although this assignment focusses on participants of the BolusCal therapy, results can show relevance to all people with diabetes who have to determine carbs (see fig.1).

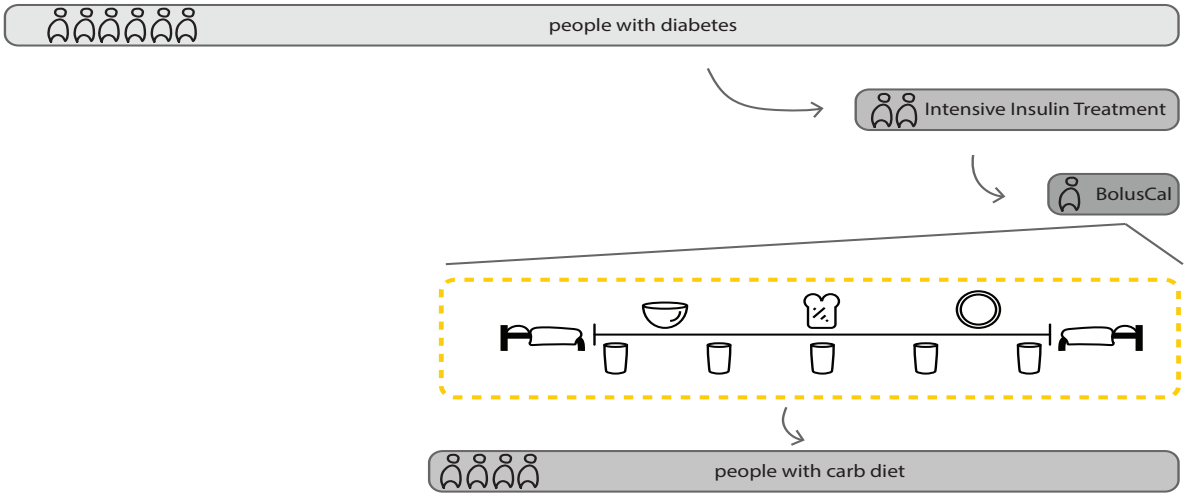


Fig. 1: Visual explaining the scope of this project, researching carb moments in the everyday life of BolusCal participants, and the significance for other people

3. Approach

This project is executed with a constant interplay of research and design, meaning that design was used to uncover new knowledge which was then used to develop design. The key to making successful products for people with diabetes is to involve them from start to end in the design process. They are the experts of their own life and should therefore have a say in what they need and what should change. By involving them in explorative research and design activities and by changing their role from patient to expert, interesting insights might come to the surface that otherwise might not have been found (Sanders & Stapper, 2012). These insights will subsequently be the foundation of the final design and the proposal made to Roche Diabetes Care.

After a short and brief analysis phase, four design-research cycles were planned for this project (see Fig. 2). In every cycle design methods were applied to generate relevant insights for research which will be used in a next design activity that will continue on the previously generated research until the focus is clear enough and the research is extensive enough to make a final design proposal. Between the cycles the design activities are used to reflect on the decisions taken and in this way used to step into the next iteration.

1.Analysis: field research and observations.
In this phase, people who participated in the BolusCal program were observed. The observations were focussed on peoples motivations to enter the therapy and reactions to the trainings and products. This phase also was reserved for interviews with all relevant involved parties: internist, diabetes nurse, dietician, account managers.

2.Research and design orientation
Determining the design direction and the scope for this project. In this phase people with diabetes could still reflect on everything associated with BolusCal, counting carbs, lifestyle changes and the impact of the program on them and their lives.

3.In-depth context research and design.
This phase is dedicated to a multiple day explorative carb session. Specific cases were designed and one-on-one research at people's homes was executed.

4.Detailing research and design.
This part would serve to try out embodyments of the research from previous cycles. Through paper prototyping and acting with healthy people, decisions could be make regarding detailing the design and interaction.

5. Evaluative research and design.
This cycle describes the research to evaluate a proposed design concept. Through a working prototype and a multiple-day test, conclusions can be drawn regarding the interaction of the design proposal and people with diabetes.

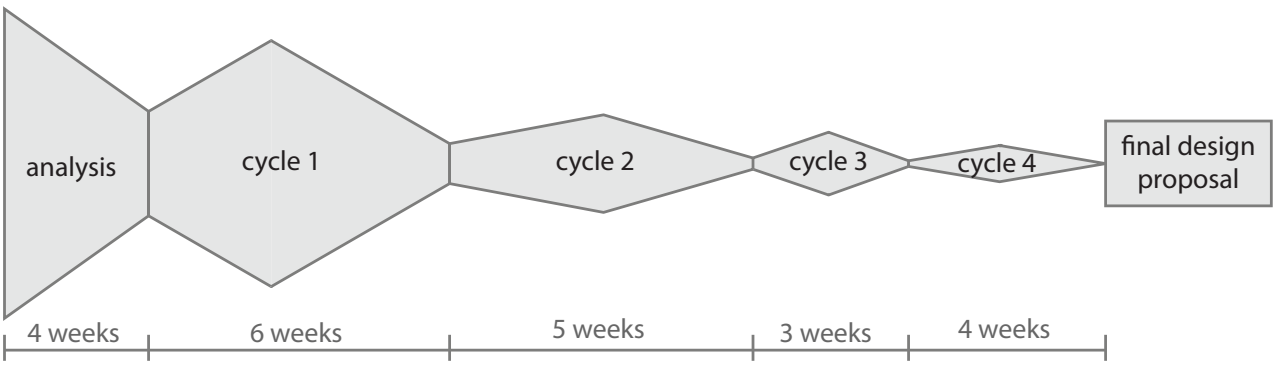


Fig. 2: Visual explaining the iterative approach of this project including the duration of every cycle

4. Report structure

The goal of this report is to present the final design for this specific assignment that is proposed to Roche Diabetes Care. However, since the four iterations form the foundations of the final design and actually contain most richness they are being presented in this report as well. They can however, each be read separately or be skipped entirely, which is not advised (See fig. 3).
A paragraph is dedicated to make the bridge from the analysis to the final design proposal by explaining which insights of the four cycles account for which design choices.

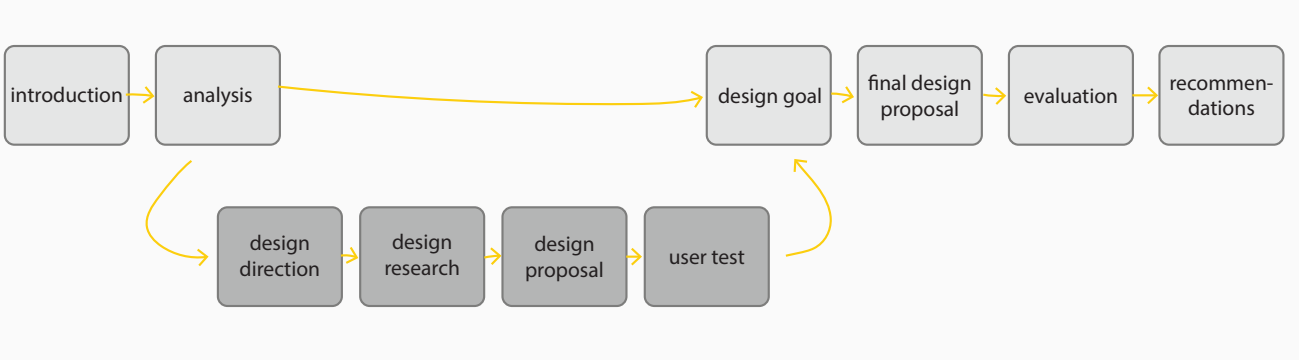


Fig.3 Visual explaining the structure of this report

5. Background information

This chapter describes background information relevant to this project. It introduces you to the company Roche Diabetes Care and it covers details of diabetes as a disease, it's therapies and the tools offered to self-manage diabetes. Secondly, carbohydrates are discussed in detail; what they are, what food or drinks contain them and how to determine the carb content.

5.1 Roche Diabetes Care

Roche Diabetes Care, Inc. is part of F. Hoffman-La Roche AG who is mainly known for its pharmaceutical work. The headquarters of Roche Diabetes Care is situated in Basel. It's goal is to help people with diabetes improve control of their health by developing products that check and manage blood glucose levels. The products that they develop range from blood glucose meters to Continuous Glucose Monitoring (CGM) devices and from lancet devices to data management systems.

The Dutch office of Roche Diabetes Care is situated in Almere and they are a distributor of the Global Diabetes Care organization. It's main tasks involve selling and marketing of the products that are bought from Global. Therapies are developed specifically for the Dutch care landscape and support should be given to Dutch people with diabetes in their usage of the products. A relatively new strategy for Roche Diabetes Care is to shift from creating value via products towards creating value via services and solutions (G. Bergman, personal communication, february, 2, 2017). Only when the needs of the patient can be translated into solutions will the implementation of products in the Dutch market be successful. The challenge is to keep up to date with current technological innovations and to offer fitting services and solutions as well in order to stay ahead of competition.

5.2 Diabetes Mellitus

Diabetes mellitus is a chronic disease which causes you to get elevated blood glucose levels either because your body doesn't produce insulin, can't use the insulin or both (IDF 2015). Insulin is a hormone that is produced in the pancreas and it is needed to transport glucose from the bloodstream to the cells where it then can be used as energy. Without insulin, glucose cannot be transported to and used by the cells and will therefore remain in the bloodstream which causes a rise in the blood glucose level. If these levels continue to rise, called hyperglycemia, the excessive amount of glucose in the bloodstream will damage tissues in the body which in the end will cause life-threatening complications (IDF 2015).

There are different types of diabetes, the three main types being: type 1, type 2 and gestational diabetes. As mentioned, this research will only focus on type 1 and type 2 diabetes because gestational in most cases will resolve after the baby is born (IDF 2015) and people don't have to make permanent changes to their life(style).

Type 1 diabetes is an autoimmune disease, meaning that the body's immune system destroys the cells inside the body that are responsible for producing the hormone insulin. This means that the body cannot produce any insulin by itself and will therefore automatically be

treated with an intensive insulin therapy. This type is most common amongst young people (ages below 30) and it accounts for around 5 percent of all diabetes cases around the world.

Type 2 diabetes is characterized by insulin resistance rather than an absolute deficiency, meaning that in most cases the body is still able to produce a small amount of insulin. The treatment for type 2 is therefore in most cases less intensive compared to type 1 because people are less reliant on the insulin injections. Type 2 can be defined in different phases: phase 1 being impaired glucose tolerance, phase 2 being sufficient insulin secretion and phase 3 being pancreatic insufficiency (Roche DC eLearning, Background of Diabetes Mellitus). Depending on which phase someone is in, the treatment is different. The first phase can at first be treated with an adjusted diet and exercise schedule. The second phase would be intensified with medication: oral diabetic agents. However, if someone enters the 3rd phase there is no other choice than to start treating with insulin. Over time it is most likely that the prescribed units of insulin will increase as the body will become more resistant to insulin. Since the disease gradually becomes worse, often when someone is diagnosed it is very likely that that person might have been having diabetes for years. In some cases type 2 can be caused by lifestyle: obesity, physical inactivity, cholesterol and high blood pressure can be of influence on type 2 diabetes (Rutten et al., 2013). If diabetes is diagnosed in an early stage in some cases lifestyle changes can remove the symptoms of diabetes and can be sufficient treatment, however you cannot be cured. Type 2 accounts for about 90% of all diabetes cases around the world.

Diabetes type 1

- **Auto-immune disease: the body's immune system destroys the insulin producing cells**
- **5% of people with diabetes have type 1**
- **age less than 30**
- **certain genes**

Diabetes type 2

- **insulin resistance or relative dificiency in insulin production**
- **closely related to metabolic syndrome**
- **age above 45**
- **can be influenced by healthy lifestyle**

5.3 Insulin therapy

Insulin therapy comes in different treatment plans. Based on the physical and mental abilities of a person will the most suitable therapy be chosen.

Conventional insulin therapy
Conventional insulin therapy. This option is obsolete for people with diabetes type 1. When someone's daily routine is very regular it might be considered to put someone on a conventional insulin therapy. The therapy is adjusted to a consistent intake of carbohydrates and can therefore prescribe consistent units of insulin. The graph below (fig. 4) describes how the fixed insulin shots behave in the body and how they compare to a healthy persons insulin releases.

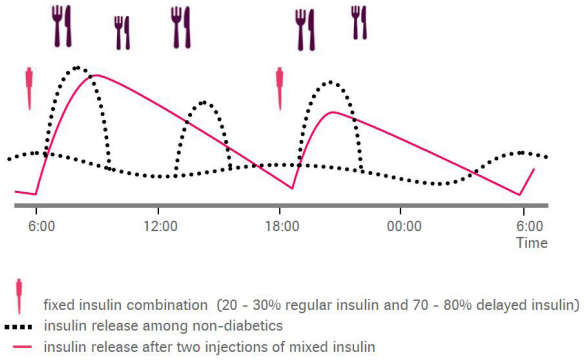


Fig. 4: A graph explaining how conventional insulin therapy reacts in the body compared to a healthy person . From Roche eLearning: Treatment of Diabetes Mellitus

Basal-bolus
The body needs a little bit of insulin during periods of fasting for the blood glucose metabolism. A healthy person's pancreas would release small amounts of insulin at all times to keep the blood glucose levels stable, whether or not a person eats. A person with diabetes on a pen therapy uses a special type of insulin to simulate this. It is a type of insulin that works for a longer period of time. Depending on what a person fits best an insulin can be chosen with an effective duration of action between 8 and 24 hours. This longer-acting insulin is called the basal injection. If a healthy person eats carbohydrates the pancreas immediately would react by producing large amounts of insulin. A person with diabetes on pen therapy simulates this by using a short-working insulin. Again depending on what someone fits best an insulin can be chosen with an effective duration of action between 1 and 6 hours (Roche DC eLearning, Treatment of Diabetes Mellitus). This short-working insulin is called a bolus injection. Fig. 5 shows that the basal-bolus scheme already simulates a healthy body's insulin releases much more accurately compared to conventional insulin therapy.

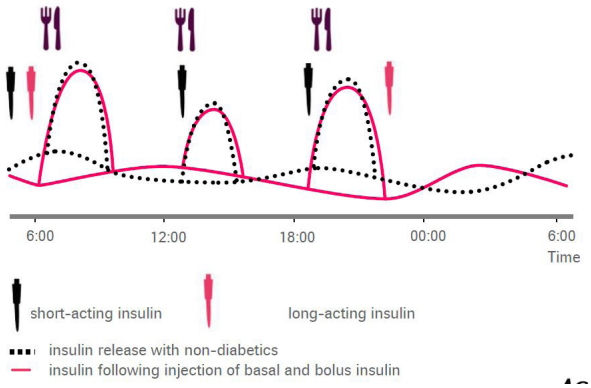


Fig. 5: A graph explaining a basal-bolus regimen tries to account for blood glucose peaks more naturally. From Roche eLearning: Treatment of Diabetes Mellitus

Pump therapy
An insulin pump is the best imitation of physiological insulin secretion right now available on the market. It creates stable blood glucose levels by constantly releasing a small amount of insulin, just like a healthy pancreas would (see fig. 6). However, the user still has to operate the pump manually to account for blood glucose rises by meals. A pump only uses one type of insulin and the infusion set has to be replaced between every 1 and 3 days, which is a lot less injecting compared to 4 times every day with pen therapy.

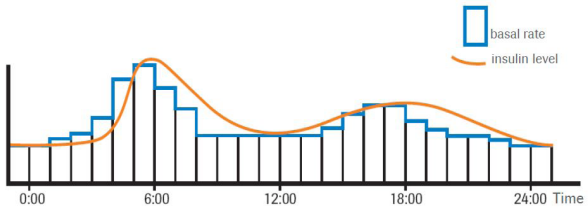


Fig. 6: A graph explaining how a pump therapy tries to simulate the insulin production of a healthy body. From Roche eLearning: Treatment of Diabetes Mellitus

5.4 BolusCal

The BolusCal progam is derived from the training concept developed in Denmark (Meldgaard et al., 2015) which is inspired by the Dose Adjustment for Normal Eating (DAFNE) study performed in Britain. The DAFNE study showed that glycaemic control and quality of life of people with diabetes type 1 can be improved using skills training promoting dietary freedom (DAFNE study group, 2002). Meldgaard et al. (2015) developed a new training concept also for patients with diabetes type 1 that was successfully implemented in routine practice and that showed improvement in HbA1c values and a decrease in follow-up consultations. They demonstrated that using a 3-hour group session and an individual follow-up appointment resulted in improved glycaemic control and patient satisfaction. The training, designed to keep support blood glucose control while providing dietary freedom (DAFNE study group, 2002), played an essential role in getting full benefit from advanced carb counting.

The goal of BolusCal therapy is that people with diabetes can get their blood glucose levels in a tighter and therefore more healthy range while still living flexibly. The idea behind the program is that since diabetes means insulin deficiency, the disease is best managed by injecting the insulin that is needed rather than by manipulating someones diet to match prescribed insulin (DAFNE study group, 2002). This means that BolusCal offers flexibility to its user; enabling them to still being able to live healthy while having to make a minimal amount of concessions in living their life. A traditional therapy would suggest to eat the same amount of carbohydrates to match the same amount of insulin administered every day. The consequence of this was that it was difficult to take into account variations in appetite and activity, often resulting in an impaired quality of life (DAFNE study group, 2002). The BolusCal therapy is based on the idea that as long as people are aware of the factors that affect their blood glucose levels, they can adjust their insulin to this and can therefore still do the things they want to while staying within the healthy blood glucose ranges.

The BolusCal program consists of three major elements: advanced carbohydrate counting, automatic bolus calculator and general diabetes training.

Fig. 7 The official information brochure of BolusCal

Advanced carbohydrate counting
Advanced carbohydrate counting (ACC) is the official term used for the detailed way of counting carbs to maintain blood glucose control by matching the amount of insulin to the intake of carbs. Multiple components are part of ACC:

1. Insulin sensitivity factor (ISF), meaning how sensitive the body is to insulin. It is a ratio that describes how much your blood glucose level drops on one unit of insulin (1 unit contains 1/22 mg insulin). This ratio can change throughout the day and can be defined in timeslots in the meter.

2. Carbohydrate:insulin ratio (CIR), describes how many carbs are covered by one unit of insulin. This ratio can also change throughout the day and be defined in different timeslots in the meter.

3. Target for blood glucose levels. This target can be different for everyone but is most commonly defined to be between 4 and 8 mmol/L. Together with a healthcare professional this target is defined and readjusted over time.

4. Insulin resistance factor. This factor can change depending on someones physical and mental state. The factor can be changed according to specific situations of for example mental stress, menstruation, illness or physical activity. Each of these factors can affect the blood glucose level. Together with a diabetes nurse, someone with diabetes can discover what the effects are and define these in the meter. Whenever they apply, the user can select these options so the algorithm will take that factor into account.

5. Insulin on board (IOB). This means the amount of insulin still active inside the body, present from a previous bolus. This is an important part of the ACC calculation because the active amount has to substracted from the new bolus to prevent hypoglycaemic episodes.

6. Current blood glucose level. This value is retrieved using the blood glucose meter.

7. Amount of carbohydrates that are (going to be) eaten

The first mentioned factors (1 to 4) have to be defined one time and can be used from then on. The amount of insulin still active inside the body is something that the meter can calculate. However, 6 and 7 are elements that the user has to define every time he wants a bolus advice. The carb intake is the most ambiguous one to define exactly because this can be different for every meal and additional information is needed to determine the carb content. All factors together are used to exactly calculate the bolus amount (see fig. XX).

Automated bolus calculator
An automated bolus calculator is a blood glucose meter with an integrated bolus calculator. Meaning that the meter takes care of the calculation presented (see Fig. 8) and can support someone with an appropriate bolus advice. The complexity of the formula shows the benefit of an automated bolus calculator, supporting people in determining the right amount of bolus insulin. Other functions are integrated as well, e.g. reminder function and the option to view the statistics of the saved data so it can be shared with a health care professional.

Training
The goal of the training is to teach participants in how to count carbs, how to use the automated bolus calculator and to improve or recollect the knowledge of diabetes and the treatment. The content of the training includes the following topics: insulin action profiles, insulin absorption, insulin sensitivity, timing, dosing and injection and measure techniques. The training consists of both theoretical and practical parts; actual food is used to explain carb estimation.

$$insulin\ bolus = \frac{current\ BG - target\ BG}{ISF} + \frac{grams\ CHO}{CIR} \times insulin\ resistance\ factor - IOB$$

Fig 8: Illustration of the elements of Advanced Carbohydrate Counting, formula from (Meldgaard et al., 2015)

5.5 Carbohydrates

Carbohydrates, or carbs, together with fats and proteins are the three building stones the body needs to function properly. Carbs give the body energy and especially the brains rely on it. When carbs enter the body they will be digested and broken down into glucose amongst others. Glucose enters the bloodstream and will be used by the tissue that will burn glucose. Carbohydrates can be divided based on whether they are simple or complex, whether they are soluble or insoluble and how fast your body can turn it into glucose. These properties of different carbohydrates become relevant for someone with diabetes when composing a healthy diet. If a carbohydrate is complex, the body needs more time to digest it. Glucose will therefore enter the bloodstream more slowly and consistently when compared to fast carbohydrates as sugar which only consists of simple carbohydrates such as glucose and fructose (Stichting Voedingscentrum Nederland, z.j.). This is relevant for someone with diabetes because fast changing blood glucose levels are difficult to keep stable and within healthy boundaries due to the fact that the insulin that is injected works slower than insulin that is released inside the body.

Counting carbs: in theory and in practice
Counting carbohydrates accurately is a laborious task. It will cost time and effort in the beginning. However, over time it will become easier. Firstly because people start to remember their usual carb intake; most people eat quite regular ingredients and recipes. Secondly, people gain knowledge of carbs and can translate their usual carb intake to unfamiliar situations. Through experience a feeling for carbs is created.

When wanting to approach carb counting very precisely you would have to know the weight of the product you are about to eat and you would have to know the carb property of that specific product. For example if you know that your apple weighs 150 grams and contains 13 grams of carbs per 100 grams of apple, than you know that your apple contains 19,5 grams of carbs in total. This is why in the beginning stage of counting carbs people are encouraged to use the weighing scale often to get a feeling for the weight of their usual portions. To retrieve the carb property of a product there are books, lists and apps provided by several parties including hospitals, companies, institutes and individuals.

However, in practice there is a limit to how accurate the carb content of a product can be determined. Firstly, people don't take a weighing scale with them so they must make an estimation of the total weight. Secondly, the carb property might not be as accurate as it is being presented in the books, lists and apps (H. Fluit, personal communication, june 2, 2017). For example potatoes might have been measured 20 years ago resulting in the properties presented on the food label but since then the potato might have changed, including it's carb properties. Also, for example peanut butter is not measured as an ingredient but it's properties are calculated based on the ingredients that it contains: peanuts, sweeteners and emulsifiers. Thirdly, properties of ingredients can change to how they are being prepared: cooked/baked/raw or with peels/bones/gratings. Not always are the carb properties defined for every situation causing that carbohydrates have to be approached approximately rather than calculated exactly. Lastly, there is the issue of how accurate is accurate enough. This is difficult to answer because this is personal for everyone: one person might need 1 unit of insulin to process 5 grams of carbs whereas another might need 1 unit of insulin for 20 grams of carbs. For some it means that being 5 grams off in estimating the amount of carbohydrates can make the difference in how many units of insulin should be injected where for another person it would make less of a difference. This can cause people to be different in how accurate they need to be.

A dietician prefers teaching people with diabetes a way to approaching carbohydrates as simple as possible rather than teaching people how to be as accurate as possible: there is a limit to how accurate you can get and a simple approach increases the chance of people keeping up with counting carbohydrates. Example of a simple approach is the rule of twenty: 1 piece of handfruit is about 20 grams of carbohydrates (H. Fluit, personal communication, june, 2 2017). In theory this is not true, a banana contains more carbohydrates than an orange and it also depends on the size of the fruit. Yet in practice this works better because it is simple enough for people to execute whereas if people would have to weigh, search and calculate they probably would not have determined the carbs to begin with.

Fig. 9: Stills of the app Eetmeter, retrieved from www.allesoverdiabetes.com

Tools available for carb information

Figure 9 displays the mobile application Mijn Eetmeter. This is an app that enables its user to analyse his own eating behavior by supplying him with information about nutrition, and by giving advice based on stored data. The nutritional information that Eetmeter uses is based on the nutrition database of NEVO (Nederlands Voedsingsstoffenbestand) and LEDA (Levensmiddelen Databank) that are being maintained by Nederlands Voedingscentrum together wtih Rijksintituut voor Veiliheid en Milieu (RIVM). These same sources are used for the Eettabel, a book containing nutritional information of most common foods in the Netherlands (see Fig. 10) and for the soon to come mobile application Etiketwijzer. The prognosis for the launch of the Etiketwijzer is octobre 2017 and it will become a tool for supplying consumers with nutritional values through scanning the barcodes of food products. All three tools are interesting because they are based on a reliable source of information but the Etiketwijzer is especially interesting because it uses a new technology that will simplify accessing information of specific products greatly for users.

Fig 10: Pictures of the hardcover of the Eetabel, developed by Nederlands Voedingscentrum

Another example of a popular mobile application is Fatsecret (see fig. 11). Again this is not an app targeted specifically at people with diabetes, it is meant for anyone who wants to use food to live a healthy life. The advantage of Fatsecret is that it contains a huge database of food information and can therefore distinguish differences in brands of a similar products or can list mixed meals. The app has access to this extensive information because every user can store data into the database, meaning the more people use the app the bigger the database will grow. Although it is nice that people from all over the world can help each other in counting carbs (amongst others) and a motivational aspect is incorporated, there is a big side note to this app. The reliability of the information can not be guaranteed. It is not always clear how someone got to a specific carb content in a dish or product so the user should be alert in copying information.

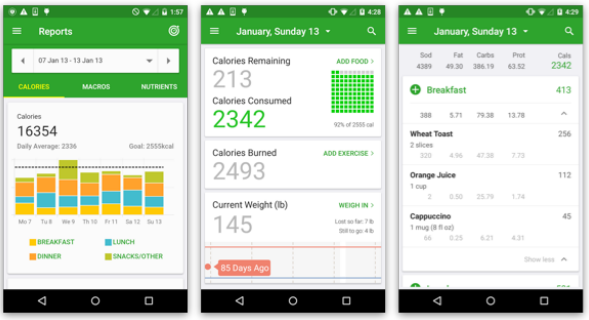


Fig. 11: Stills of app Fatsecret (retrieved from www.mobile.fatsecret.com

An example of a mobile app that goes further than supplying nutritional information and enabling data storage is mySugr (see fig. 12). This app is specifically designed for people with diabetes with the aim to improve the experience of diabetes self-management. It offers education, encorporates all diabetes data management including blood glucose values and uses playful elements (e.g. characters, visuals and challenges) to motivate users.

Fig. 12: Stills of app mySugr, retrieved from www.mysugr.com

Figure 13 shows an example of a variation list supplied by the hospital in Twente. Such lists are given to people with diabetes to help them on their way in counting carbs. It enables people to go from portions to carb content in one step without having to weigh or calculate. The hospital does advice everyone to check whether the numbers on this list check out with what people actually consume. For example it could be that someones spoon is much bigger and therefore contains bigger portion sizes than presented on this list.

There are many tools available for people with diabetes to access carb specific information. Some tools provide its users with access to huge databases while others provide options for data logging or achieving goals.

However, the fact that there are so many different sources is also part of adding complexity to carb counting because they sometimes contradict each other which makes it difficult to determine what can be trusted. There is not yet one ideal tool for supporting diabetes self-management while gaining access to reliable and accurate carb information of Dutch food products. MySugr makes a good start because it is designed specifically for people with diabetes. It incorporates relevant education and motivational challenges. However, it is not enough (yet) for completely rely on for determining carbs.

levensmiddel	**eenheid**	**gewicht**	**kh**
		in gram	**in gram**
A			
aalbessen	schaaltje	100	5
aardappelen			
- gebakken	aardappel opscheplepel	50	8
- gekookt	stuks	50	8
- kroket	stuks	30	8
- puree	aardappel opscheplepel	50	7
aardbeien	schaaltje	100	5

Fig. 13: Variation list of frequently eaten food, by Ziekenhuis Groep Twente

5.6 Tools

TOOLS PART OF BOLUSCAL

Accu-Check Aviva Expert

The Aviva Expert is a product of Roche DC and it is the meter that is part of the BolusCal program and that calculates a bolus advice based on the input that the user enters (see fig. 14). It is part of the Accu-check portfolio by Roche Diabetes Care. The meter works with separate blood strips that are supplied in a separate bottle. To be able to put a drop of blood on the strips a pricking device is also part of the products. These products together enable the user to check the blood glucose levels.

Fig. 14: Aviva Expert, the bolus calculator of the Accu-Check portfolio by Roche Diabetes Care, retrieved from www.accu-check.nl

OTHER TOOLS THAT CAN BE COMBINED WITH THE AVIVA EXPERT

Insulin pen or pump

Next to these products a person with diabetes also needs a device that takes care of the insulin insert. At this moment Roche Diabetes Care offers only insulin pumps and no insulin pens. Both are possible to use in combination with the meter. When using a pen, the user has to turn a wheel to select the amount of insulin units and inject this inside the body. Most common places are in the stomach or thighs. When using a pump, the insulin enters the body via an infusion set (see fi. 15). The pump makes sure that a small amount is released throughout the day just like the pancreas does in a healthy person's body.

Fig. 15: Insulin pump oby Medtronic, retrieved from www.medtronic-diabetes.nl

Continuous Glucose Monitoring

The next big thing on the market is Continuous Glucose Monitoring (CGM). These are meters that are inserted in the body, e.g. on belly or upper arm (see fig. 16), and that measure the blood glucose levels at all time. This makes it easier for a person to monitor his/her blood glucose levels without having to prick a finger every time. Also this creates a great opportunity to understand how the blood glucose levels act throughout the day and makes it easier for someone to understand the body. If such a CGM system could be connected to an insulin pump then there would be a closed-loop system; an artificial pancreas. At this moment the algorithms are not reliable enough but it seems only a matter of time before this can be realized (Arends et al., 2009).

Fig. 16: The CGM system of Eversense, retreived from www.eversensediabetes.com

Other innovations involve insulin that can be inhaled via lungs or meters that can measure the blood glucose levels via the eyes, tissue fluid or saliva. All solutions could make the life of someone with diabetes much easier because they decrease or even eliminate actions to manage diabetes and worries moreover. (Arends et al., 2009).

Tools for carb counting

In the previous section tools were presented that allow access to carb specific information of different ingredients. However, to count carbs more information is needed than only the carb ratio of ingredients: the total weight of the different ingredients. There are tools being made to make counting carbohydrates more convenient and accurate by offering support in weighing. Most of these innovations work with a weighing scale that is connected to a database containing food nutritional values. Three tools were selected to present here based on their differentiating factor and current popularity on internet.

Fig. 17: The SmartPlate. retrieved from www.getsmartplate.com

Fig. 18: The Smart Scale. retrieved from www.smartdietscale.com

Figures 17 and 18 present two examples that provide interesting opportunities for people to make carb counting more clear, easy and accurate at home. However, people cannot take these products with them when they leave. Although the SmartPlate can still provide support using only an application the accuracy of the data will decrease without using the scale.

Fig. 19: EasyCarb. retrieved from www.easycarb.org

Figure 19 presents an initiative in which the scale is designed to be taken with you, enabling to calculate carbs accurate whereever it is necessary. Yet, this solution does not add to the freedom of someone with diabetes. It would be yet another product people have to take with them when leaving the house.

These three tools are great for supporting people to be more accurate in determining their carb content but they have the risk that people become dependent of them and of the context in which they are likely to be used. It would be a shame to combine BolusCal with such tools because it takes away the flexilbility where BolusCal stands for. People should instead be supported in determining their carb content independently yet still confidently.

Tools were mentioned that are currently available to people with diabetes to support them in managing diabetes or that might become available in future. The support they offer range from moniroting blood glucose values, injecting insulin, accessing data and counting carbohydrates. With improving technology, people with diabetes can be supported more and better in their diabetes self-management. However it also causes a dependence on the technology and the products. With tools piling up for someone with diabetes the question rises whether more products will actually contribute to more ease and whether people will accept having to use more diabetes products.

5.7 Behavior change

As previously discussed, diabetes should be managed at all times. When asking people to change the approach of their diabetes self-management actually means asking them to change their (habitual) behavior. Meaning that this project involves in behavior change and therefore in the psychology behind behavior change. Many models and theories have been created naming different or comparable determinants for behavior change. This section will describe two of much researched theories and highlight in particular one important aspect of both.

Social cognitive theory

Social cognitive theory (SCT) evolves around the concept that we learn by observing others. Unlike other (earlier) theories that mainly consider personal and social factors (rewards, barriers, social norms etc.) to determine behavior, SCT states that behavior is the product of the dynamic interplay between personal, environmental and behavior determinants (Glanz, Rimer & Viswanath, 2008, p.170). Rather than stating that the environment changes people's behavior, SCT states that people can also change their surrounding environment for their own purpose. This view broadens the perspective of the determinants that influence behavior change.

People and their behavior are too multifaceted to be placed in a few categories or for their behavior change to be placed in fixed stages with a fixed sequence (Bandura, 1998). Rather than describing behavior change in seperate stages, SCT poses that people fluctuate in exercising control over their health related behavior. Their behavior is a result of the interaction between personal, behavioral and environmental factors (see Fig. 20). Any intervention to change someones health related behavior should be tailored to the determinants that influence his health habits and to his progress rate. Bandura (1998) describes a basic approach to influence behavior through changing the environment through fascilitation: the environment should support the new behavior. (Glanz, 2008 p. 173). Facilitation plays an important role, because resources enable the behaviors to take place and to make them easier to perform.

Several studies have shown that the performance of many behaviors is determined by one's expectations of the outcome and one's self-efficacy (REF XX). Self-efficacy is the belief of being successful in a task. Outcome expectations is an important determinant for the SCT, it describes the likelihood of an outcome that might appear after performing a certain behavior as well as the perceived value of that outcome.

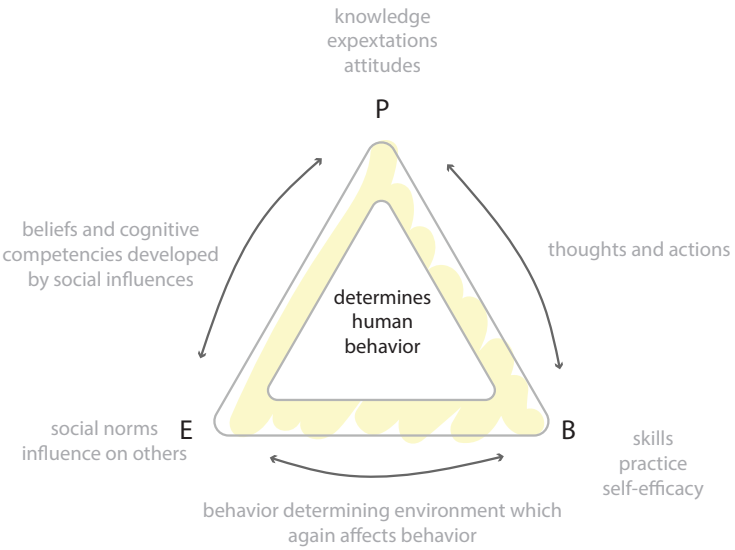


Fig. 20: Banduras triadic resiprocal causation model, explaining how all determinants influence each and together form behavior (Bandura, 1994)

Self-efficacy

Self-efficacy belief is the concept for which the Social Cognitive Theory is particularly known. The bigger the complexity of a to be performed behavior grow the more important self-efficacy belief becomes (Glanz et al., 2008, p. 172).

Self-efficacy is defined as "the conviction that one can successfully execute the behavior required to produce the outcomes" (Bandura, 1997). Efficacy belief plays a major role in whether a person will undertake action. There is little incentive for someone to persevere when being faced with difficulties if he does not believe that he can produce the desired effects with his actions. Motivation is founded on believing that certain actions will bring the desired changes. This is also true or adopting and maintaining health related behavior (Bandura 1998).

Four specific sources of influence on the development of self-efficacy have been distinguished by Bandura (1994):
1. Master of experiences. By experiencing success the belief in one's personal efficacy is increased. In the same way does failure undermine the level of self-efficacy. However, it has to be noticed that easy successes cause a bigger chance on discouragement when failure occurs. In building a resilient sense of self-efficacy some effort and perseverence is needed.

2. Social modelling. By seeing someone similar to yourself succeed in a task raises your belief that you can

succeed as well. Next to being able to compare against someone else, models also provide an opportunity to transmit knowledge to observers and to learn them skills and strategies.

3. Social encouragement. By verbally hearing that you will succeed increases the belief that you have what it takes. People who are persuaded of believing in their own capabilitites are more likely to make a greater effort and sustain.

4. Improving emotional and physical state. By being able to correctly judge emotional and physical reactions one's belief of efficacy can also be modified. For example a positive mood enhances self-efficacy whereas wrongly taking physical pain for lack in stamina decreases self-efficacy.

In BolusCal the participants are taught that they can learn to control their diabetes. Such a self-management program can greatly increase their efficacy in that they can control their own physical condition (Bandura 1998). However, once arriving at home no model is present any more to learn people how to change their behavior. Extra support might be needed to guide people to mastering skills in practice.

Health belief model

The health belief model (HBM) describes and tries to predict health behavior of people using their attitudes and beliefs. It uses several concepts to explain why people will take an action to either check, improve or prevent illness:

1. Perceived threat. This construct can be split in two: perceived susceptibility and perceived severity. The first concerns the likelihood of getting a disease and the second concerns the feelings of seriousness of this disease were it to happen or were it to be left untreated (including medical, clinical and social consequences).

2. Perceived benefit. Even if someone perceives a threat, whether action will be taken is influenced by the perceived benefits of that action, whether it is perceived to be beneficial for reducing the threat of the disease.

3. Perceived barries. This explains the potential negative effects that the intended action might cause. For effects such as expenses or physical inconveniences can be reasons not to undertake the proposed action.

If someone perceives him- or herself to be susceptible to a certain disease, views the effects of this disease to be severe, believes that undertaking a specific available action would benefit the situation and would judge that the potential benefits outweigh the potential barries than this person is very likely to undertake the action. The combination of beliefs, with the right cues to trigger action would then lead to behavior change.

As can be seen in figure 21, self-efficacy is now part of the HBM, where it was not incorporated in the original model. However, many studies have shown the importance of self-efficacy for initiation and maintenance of behavior change (Bandura 1997) which is why it has been added to the HBM.

Both SCT and HBM explain and predict (health) behavior and include constructs and relations of knowledge, perceptions and actions while underlining the importance of building self-efficacy. These theories will be used in the next chapter to explain the behavior observed in the training sessions of BolusCal and will be used to lay a theoretical foundation for the final design proposal.

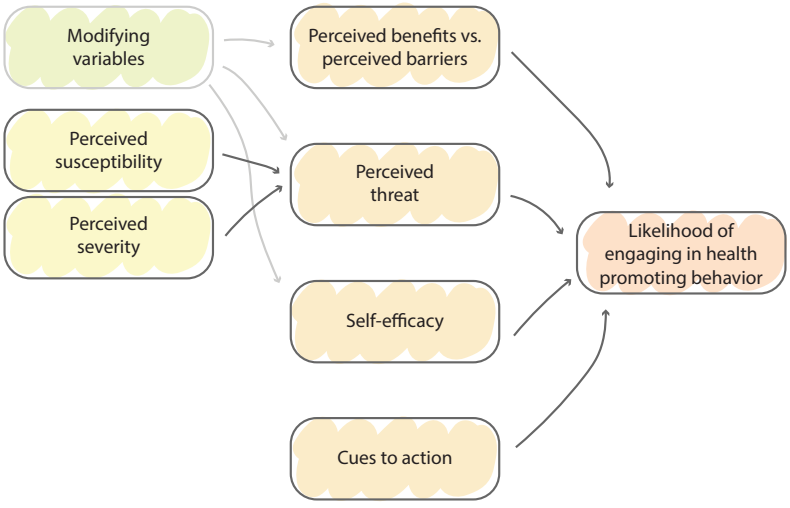


Fig. 21: The Health Believe Model with the addition of self-efficacy (Glanz et al., 2008).

6. Context Analysis

When someone with diabetes get placed in Intensive Insulin Therapy, multiple healthcare professionals will be involved in this treatment: an internist, a diabetes nurse and a dietician. All three have a different role and are responsible for overseeing different aspects of the treatment and development. The accountmanagers of Roche DC visit hospitals and healthcare professionals to sell the BolusCal program. This chapter describes the different roles of these different stakeholders and highlights the relevant insights gained from interviewing them.

Semi-constructed qualitative interviews were held with 2 account managers of Roche DC, with 1 internist, 1 diabetes nurse and 1 dietician. Topics that were discussed in these interviews were their opinion of BolusCal, which criteria they use to refer their patients to the BolusCal program, their judgement of what is most difficult for people with diabetes and what might be reasons for people to stop with the program. The interviews have been summarized and will be presented below one by one.

6.1 Interviews

ACCOUNT MANAGERS

Interview with Marielle Linssen and Pascal Wiggers, account managers Roche DC

At this time, the program BolusCal is only unrolled in the second line of healthcare, meaning all healthcare for which a referral is needed, e.g. hospitals. People who are diagnosed with type 1 diabetes are immediately referred to a specialist in the hospital (second line) wherease most people with type 2 diabetes who are not in IIT therapy stay with their General Practicioner (GP) in the first line of healthcare.

The accountmanagers of Roche DC are responsible for representing the Accu-check portfolio to healthcare professionals. If the specialist and the hospital wants to adopt the BolusCal program the account manager will supply them with all materials including user products and training materials. The account manager will then organize a training in which dieticians and diabetes nurses are trained in giving the BolusCal training. In most cases they will be present during the BolusCal trainings to help out with the meter.

Willing to be treated and motivation

The interviews with the two account managers of Roche DC pointed out that the idea of the BolusCal treatment is good but that there are issues that can cause the treatment to fail. The first is that a treatment will only work when the person with diabetes wants to be treated. Some people can be stubborn, rightly or wrongly, causing changing and adapting to a new therapy to be difficult things to do. If there is no intrinsic motivation other than the motivation of wanting to please a diabetes nurse the therapy is most likely to fail or in any way will not be most effective. No matter what a healthcare professional tells them they will hold on to previously learned habits. This might be out of convenience or because they do not feel the urgency in doing things differently; they feel fine right now. This connects to the MDI Experience Study (Sleeswijk Visser, Hoog 2016); it is more difficult for people to change for long-term health consequences compared to short-term consequences.

"The treatment succeeds or fails depending on whether the patient wants to be treated"

"We can't be a personal coach to every patient."

Information overload

The second issue is that for many people the BolusCal therapy asks for a lot of new knowledge. Some of it might be repetition of what people have learned when being diagnosed, but this might have been a long time ago and much is new or has changed e.g. faster working

insulin has been developed and diet recommendations have changed. Many participants experience that the training presents them with too much new information at once that has to be applied right away. The combination of this information overload with suddenly changing daily routine causes many people not to keep up with the therapy in the first weeks of the therapy.

"Patients feel overwhelmed with information after the first training"

Room for different behavior
Lastly, the therapy works with an ideal behavioral pattern. However, people are human and are therefore bound to break this pattern once in a while. Based on the experience of account managers, people will always find a way past the intended or designed way. The training and therapy work significantly less when people don't do what the therapy asks them to do. Rather than ignoring that people might behave differently than is ideally asked of them, time should be spend to discuss how people should act when not behaving as intended. The therapy should include a fall-back scenario so people feel equiped to handle every situation.

"Patients are always very interested in practical information: what to do when something goes wrong?"

INTERNIST
Dr. Bianchi, internist in Zuyderland Heerlen
The internist is the specialist who is in charge of the treatment of someone with diabetes. He carries final responsibility, sets out the treatment plan and will oversee the overall progression of diabetes and someone's health state.

Difference in prior knowledge
People with diabetes type 1 get send to the internist straight away. People with type 2 go through a different trajectory. They first go to their GP or Praktijkondersteuner huisarts (POH), only once they have to enter MDI therapy they get referred to the hospital and internist. Usually this takes up quite some time (this can be years) which causes a difference in how they approach diabetes compared to people who have to start MDI therapy right away. This difference shows in the BolusCal therapy; often motivation and attitude is different. Every person with diabetes, whether t1 or t2 early stage or late stage, can benefit from carbohydrate education. It might therefore be better to start educating people with t2 also from an early stage.

"The hospital is the knowledge centre for diabetes. T2 patients who first get treated by their GP or POH for years enter the program very differently in terms of knowledge and motivation compared to T1 patients"

Shame
Dr. Bianchi mentioned that his most dangerous patients are the ones who are doing very well in their check-ups. There might be embarrassment at play between the internist and the patient. Diabetes is a self-management disease that takes place in everyday life, causing people to react defensively because it might feel like their behavior is being criticized. Sometimes he feels ashamed to question how people are doing with their diabetes because all the numbers seem to be positive which can cause issues to go by unnoticed. If people are not totally honest about how they are doing or feeling than you might be surprised by sudden complications.

Responsibility
Since the treatment of diabetes takes place wherever people with diabetes are, it is sometimes difficult for the healthcare professional to find out how people are actually doing. A lot of responsibility therefore lies with the person with diabetes. Only on his initiative will problems be discussed and treated meaning firstly that he has to be aware of problems and secondly that he has to take action. For some people this amount of responsibility can cause issues.

"The patient carries too much responsibility"

DIABETES NURSE
Hanny van Vroenhoven, diabetes and research nurse MMC
The diabetes nurse works in close contact with people with diabetes. Responsibilities are informing people with diabetes about influences on diabetes regulation, supporting in lifestyle behavior and promoting self-management.

Peer contact
The trainings of BolusCal are given in groups of about 8 people (not including partners). Often people react very positively on being amongst other people who also have diabetes. For them it is interesting to share experiences, blow off steam about personal frustrations but also to learn how other people experience and approach diabetes. It gives them the opportunity to compare and assess how they are doing, removing insecurities that they are not doing so bad or motivating them to try a little harder.

"We always get positive reactions on the group format of the trianing, people value the peer contact"

Follow-up appointment
When the two trainings are over it is important that the diabetes nurse initiates contact with everyone after two weeks of applying the newly gained knowledge at home. This gives people the opportunity to ask questions and should motivate them to keep up.

"A follow-up appointment after the tainings is very important to give people that extra help or motivation that they need"

Food diary
In between the two trainings people are expected to maintain a food diary. It is a paper format diary in which people have to record everything they eat and measure in blood glucose values before and after every meal. For most people this means that they have to measure their blood sugar far more often than they usually do (7 times a day instead of 2 or 4 times a day). Also, it takes a lot of time to think about the carbs in every thing they eat and drink. Finally, writing down everything on paper often proves to be a cumbersome task that is too much work.

"The forms and food diary always get complained about. They are too much of a hasle."

DIETICIAN
Helga Fluit, dietician Haaglanden Medisch Centrum
The dietician plays an important role in the treatment plan of someone with diabetes. Responsibilities are to explain food and nutrition and the influence they have on diabetes. In practice this does not only cover how people should behave and what they should eat but how people can best fit such a behavior into their life.

Personal approach
Not everyone is suitable for a strict diet. It is more important that people are aware of what they are doing and how that influences their body and diabetes rather than that they make all the right choices all the time.

"For me it is most important that a patient finds a way to count carbs that works for him or her, even if it means not being accurate, otherwise he will give up entirely"

Reasoning more important than result
A dietician would prefer that someone can approach counting carbs as easy as possible over trying to be as accurate as possible. There is a limitation to how accurate you be in your estimation and if it is easy the person is probably better capable of implementing it in his life.

IN CONCLUSION
The relation that someone with diabetes has with each of the above named stakeholder can be quite different. Based on the interviews the personal level of the relationship that each of them has with the people they treat could be assessed (see fig. 22). This gives an insight in the extension of the influence that different stakeholders have but also highlights the personal involvement of the treatment and the source for motivational and behavioral support towards the people they treat.

The interviews resulted in insights regarding information overload, missing a follow-up appointment, the difference in people's motivation and attitudes and several insecurities. These are all potentional reason for people not to be successful with the BolusCal therapy. However, offering people the right support at the right moment might be enough to remove such insecurities and push them into the right direction of determining their carbs and self-managing their diabetes.

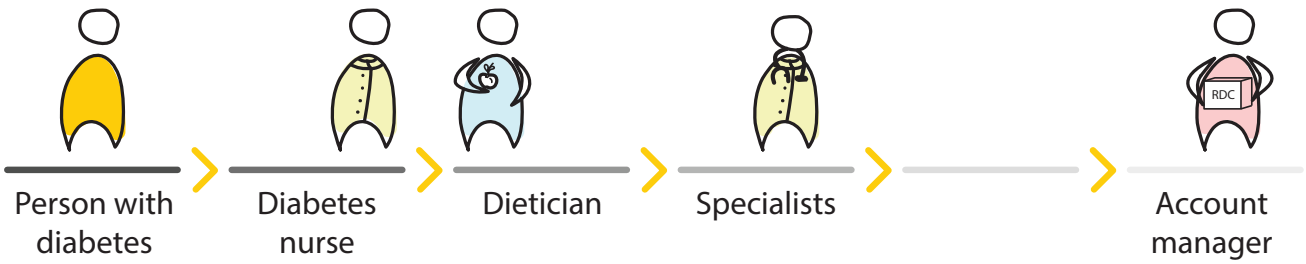


Fig. 22: Visual explaining how different stakeholder have different relationships with a person with diabetes, left being a personal close personal relationship and right a distant relationship.

6.2 Observations

Trainings in Máxima Medisch Centrum Eindhoven and St. Antonius hospital Utrecht were observed. In total 4 trainings were observed, both the first and second training in Eindhoven and Utrecht. There were differences in how the trainings were executed between the two hospitals. MMC Eindhoven has been one of the parties involved in developing the BolusCal program for the Netherlands, so they are very aware of it's goal and content, developed by Roche DC. This was less clear in Utrecht, where the diabetes nurse and dietician were less experienced in giving the training. The most important insights of the observations are summarized into insights and presented below. In Utrecht 8 people joined the two trainings and in Eindhoven 7 people joined the two trainings.

A BolusCal training consists of two half-days. On the first day topics that are discussed are: basics of diabetes, insulin and how the body reacts to it, basics of carbs, introduction of the new meter and a practical exercise with weighing and calculating carbs. The second training is focussed on reflecting how the past 2-3 weeks went, discussing ratios and whether they have to be adjusted and special attention is paid to how health conditions can influence blood glucose levels and how the meter can also take those into account.

Main insights

No big picture of information and responsibilities
Many things are unclear for people with diabetes, even for people who are living with it for over 30 years. Understanding the basics of diabetes is one thing, but you need more than a basic understanding to know how to cope in all kinds of different situations: illness, holiday, exercising, going out for diner etc. Also, there is a lot of unclarity in the finances and supplies of diabetes products. Due to different deals that suppliers have with health insurances, companies or hospitals people with diabetes get different information on what they can reimburse and which brand they should go for. During the training there were visible frustrations amongst the participants about these unclarities and there was a need for clear answers and simple rules, but with diabetes no simple rules can be given because everything is so personally dependent. People are advised to create their own simple rules through trying out and gaining experience.

Difference in motivation to join
Participants of the trainings decided to join for different reasons. There were a few who had experienced a medical episode and had decided that they should become more serious, others noticed that they missed knowledge to manage diabetes well and wanted to learn more. However the majority was sent by their diabetes nurse and they joined the program with the idea that "it wouldn't do them harm to know more". This difference in motivation to join the trainings caused a difference in how they joined: open attitudes versus defensive attitudes were observed. Also not everyone was aware of what joining BolusCal meant. Some were under the impression that they would join 2 courses to learn more about diabetes whereas it means starting a new therapy which includes using a new meter.

"I don't let diabetes take over my life"

Appreciation for peer support
As already mentioned in the interview with the diabetes nurse, indeed the contact between people who have diabetes was very much appreciated. It caused frictions between some participants as well as feeling of motivation amongst them.

Carelessness in attitude and behavior
Several times people mentioned that they treat diabetes carelessly. They emphasized that it is more important to them that they can live their life than to have good blood glucose levels all the time. This in itself is not totally bad because they can still live happy with a positive attitude. However, it does imply that they don't take long-term effects very seriously and that a little effort is already

Fig. 23: Training session of BolusCal in Utrecht, left is dietician and right is diabetes nurse

too much, which is problematic for the success of the therapy. For some it even seemed a sport to frustrate their personal healthcare professional.

"My name is ... and I am the most careless diabetes patient you have ever met."

"I never do what my diabetes nurse tells me to do"

Information overload
The first training overloaded people with information. Although people mentioned that they learned a lot it was clear that not everything had gotten through to all of them. This became clear when people returned to the second meeting when people had been using the meter in the wrong way. Although this was noticed by the diabetes nurse, there is no room in the group training for extensive individual education.

Fallback into old habits
When returning the observation was made that only 3 out of 5 participants had been dedicated to measuring blood glucose levels, counting carbs and recording everything. It is an essential part of BolusCal because based on the food diary the diabetes nurse can calculate personal data to be entered in the meter. The change proved to be too much for the others to apply at once. People enter the training with a certain behavior and approach, in the training they learn what to do in future and right after that they have to implement this new behavior. If this change is too much for someone than it is likely that he will fall back into old patterns. It might be that the current training asks too much of its participants. Glanz et al. (2008, p.14) describe that having to change more behaviors at once can be daunting. People of the Diabetes Stages on Change study could not take up to more than 2 behaviors at once (smoking, healthy diet and glucose management control). The participants of the BolusCal training are asked to change how they control their blood glucose levels, develop skills in determining their carb intake and to record and reflect on everything.

"I know everything but I just can't get myself to do it"

"I know my body best and I know exactly where my pain points are."

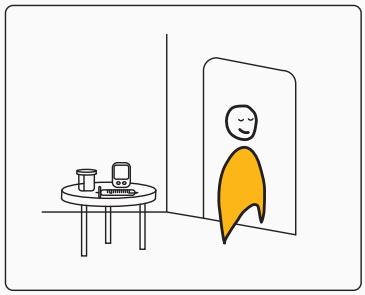
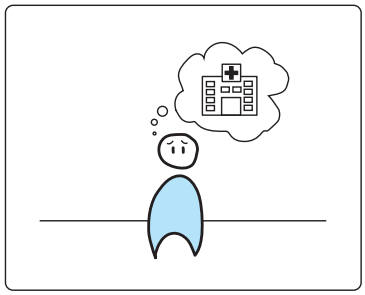
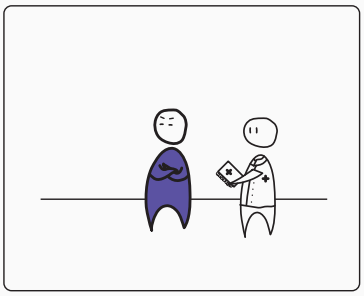
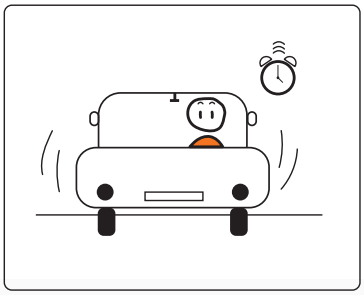
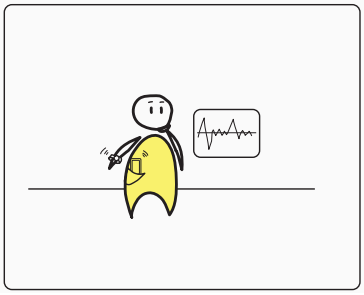
Relation to theory of behavior change
As explained in the previous chapter, behavior change can be influenced through several determinants. Knowledge is one of them in Bandura's triadic reciprocality. No concrete learning strategy is offered. People are advised to try things out at home, as to lower the barrier. However, it only lowers people's self-efficacy: people don't know exactly what to do and can therefore not determine whether they will be successful or not.

Outcome expectancy is very important for behavior change to be maintained (Bandura, 1998). During the observations it became clear that people join the training under very different expectations. Also the motivation to join was very different amongst participants. The ones who had experienced a medical episode clearly perceived the threat, benefits and looked differently upon the barriers (HBM, p.26). Whereas, the ones who were forced to go by their diabetes nurse clearly did not perceive any threat in the near future which caused them to join the session with less motivation and careless attitude.

6.3 Archetypes of BolusCal participants

The observations of the people in the trainings did not only give insights into an analysis of the therapy but also of how different people approach diabetes differently. All participants were characterized by their experiences with diabetes, attitude and behavior during the trainings. Next, differences and similarities were identified between the 15 persons which could be used to make clusters and create 5 different archetypes, presented on the next page.

Rather than observing behavior and categorizing people according to the description of their behavior, it might be more useful to provide the explanation for why people behave the way they do (or do not behave the way they should). The different determinants for people's behavior, e.g. risk perception, efficacy belief, outcome expectations etc., might call for different strategies and interventions to be transformed in the desired behavior change (Bandura 1998). This approach resulted in archetypes defined by their behavior and the reason why behavior change at this point would be difficult to establish or maintain. Since these archetypes are based on the observations of 18 people, they are not presented as being the only 5 existing archetypes. However, they serve as an inspiration of how people with diabetes can be approached differently according to their current behavior to maximize the chance of achieving success in adopting a new behavior. This analysis of archetypes can later be used to determine what type of support different people might need to succeed in improving in diabetes self-management.

	BEHAVIORAL CHARACTERISTICS	TAILORED INTERVENTION based on HBM (Glanz et al., 2008)
The optimist		
	Feels nothing applies to him/her Thinks everything will be alright Makes no concessions in life(style) Makes no effort *"I don't need al those tools and rules, I feel fine!"*	- **No perceived threat:** doesn't recognize being ill; . - Needs external input to perceive the threat - Could possibly benefit from observing a model.
The worrier		
	Worries a lot about diabetes Is set in habitual behavior Adapts life to diabetes Experiences stress often *"I can never go somewheter without thinking about my diabetes."*	- **Very low self-efficacy** - Needs guidance to create secure feeling: can I trust this? - Recognizes the disease but doesn't understand or believe what actions would cause change. - Possibly needs knowledge and the right fascilitation for empowerment.
The stubborn		
	Has tried many things in vain Always knows better; expert of own body, not the diabetes nurse Trust issues *"I have tried so much already but nothin works, I know my own body best""*	- **No perceived benefit:** does not see that actions might lead to health improvement. - Might be caused by former negative experiences which caused decreased self-efficacy. - Possibly needs guidance and proper feedback of improvement.
The busy bee		
	Puts work and life before diabetes Wants to make the effort but cannot find the time / fit into existing lifestyle *"I'm too busy to think about my diabetes all the time."*	- **Perceived barrier is too high** - Possibly needs social support to create room to sustain new health behavior
The demander		
	Wants to make effort for healthy life Feels neglected by health system Feels frustration for lack in information and innovation *"Why is the diabetes sector so much behind on offering smart technologies to people?"*	- Can adopt behavior as long as it is in line with the expectation. - However, the **barriers** of cumbersome actions grow too big over time causing feeling of being held back by tools and technology. - Possibly needs support better fit to his needs.

6.4 Conclusion

There are various elements of the trainings that could be changed to improve what people pick up from it. For example, the setup of the training could be changed so there is room for a more gradual approach preventing people to overload. First let people understand, then practice and build skills to next start applying those skills for the therapy. This approach gives people the opportunity to experience success and build self-efficacy (Bandura 1998). However, the most important insight retrieved from the observations is that people have different characters which defines how they approach diabetes and how they should be approached in adopting a new diabetes self-management behavior. This difference in approaches and attitudes is crucial to understand because it will lead to more fitting design concepts.

The next four chapters will explain the four design cycles of this project. Each iteration had it's own research objective, design methods and valuable insights to give this project more focuss with every iteration. Many people with diabetes have been involved in these iterations, causing these chapters to contain most richness of this project. These cycles form the basis for the goal, direction and solution of this project.

7. First cycle

This chapter describes the first iteration of this project. In this stage the focus was on investigating where insecurities and inaccuracies arise in the program. This is done through an explorative session in which people participated who joined the BolusCal program between 1 and 2 years ago. The insights gained from their experiences will be used to formulate a direction for this project.

7.1 Goal

The first cycle was meant to teach about the struggles and successes from experience experts; people who have participated in the BolusCal program and who have had the time to integrate that new knowledge into their lives. The goal of the session was to recap how they had experienced the learning trajectory at that time, to identify moments at which extra support could have helped and to discuss what had changed since participating in BolusCal.

Main question:
How do people experience the current BolusCal program?

Subquestions:
1. What was perceived as most difficult about learning to count carbohydrates?

2. What is the effect of the training and the program on people's lives?

3. Looking back, what could have helped while applying the new knowledge?

4. What happened when people with diabetes came home after the training and had to apply all new knowledge?

7.2 Method

An explorative session was organized in cooperation with Máxima Medisch Centrum in Eindhoven. In total 4 people joined who had participated in the BolusCal training between 1 and 2 years ago. Contextmapping was used as an example to shape the session (Sleeswijk Visser et al., 2007), which itself consisted of two parts: a reflective exercise and a brainstorm exercise. Also the participants were given an assignment 3 days upfront the session.

Priming with pictures
Before the session the participants were given a sensitizing exercise. By priming the participants they were forced to already think about diabetes and what it means to them (Sanders & Stappers 2012). In this way they would already filter the most important thoughts and emotions making the session in itself more meaningful.

Three days upfront of the explorative session, the participants were to make pictures of every moment at which they were doing something that had to do with diabetes. These pictures were then sent to the organizer of the session. In this way the participants were being confronted with the moments in which diabetes plays a role for them, something that in everyday life can easily go by unnoticed. Also the organizer could already get a sneak peek into the lives of the participants, making it easier to ask the right questions during the session. The pictures could be of anything; the most obvious moments being eating, checking glucose levels or injecting insulin.

Fig. 24: A photo of three of the four participants discussing how to approach counting carbs using a list

Storyline

The session itself was divided in two parts: creating a storyline and brainstorming about specific moments using the previously made pictures. The storyline was a tool to get the participants thinking about the passing of time. Through this exercise the participants reflected on what had changed in their life: how they approached diabetes before and how they approach it now. It brought difficult periods to the surface and caused realization of their growth.

Picture brainstorm

The pictures that the participants had made during 3 days were printed and put on the table. By laying them out everyone could look into the other person's moments and created an opening into someone's life. The images were a powerful tool to bring the participants closer to each other and start interesting discussions why something was e.g. annoying or not. Some moments were very recognizable for everyone whereas other moments only applied to one person and therefore was intriguing for the others. By letting the participants look at the pictures and start conversation automatically the most interesting moments were selected by them, which could than be zoomed on.

Data analysis

Sound records were made of the session and all interesting quotes were gathered together with the post-its of the timeline. Clusters were made of this collection of post-its (see Appendix A) and summarized into insights.

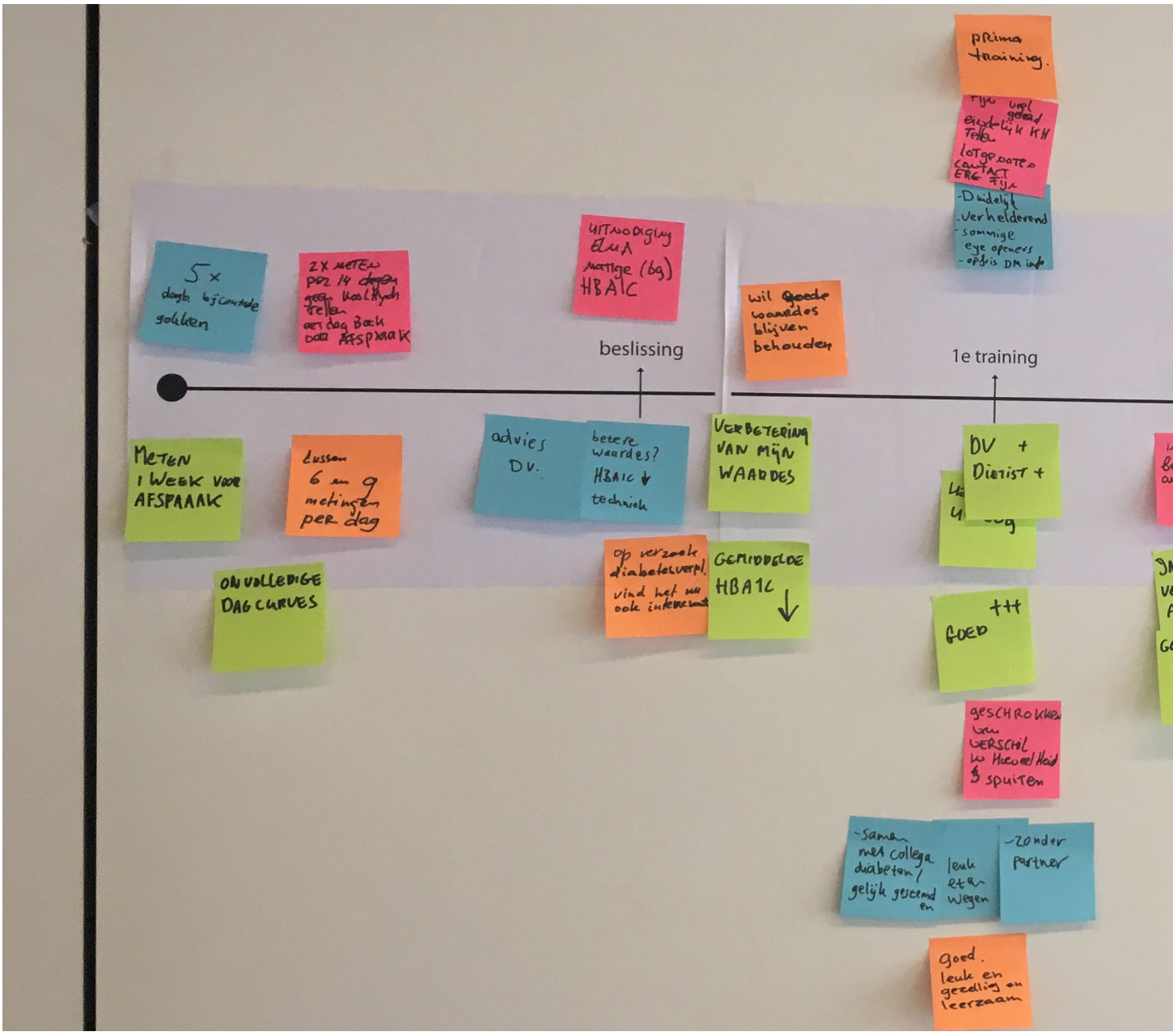


Fig. 25: Picture showing all photos send by the participants three days before the session. They served as conversation triggers and brainstorm starters

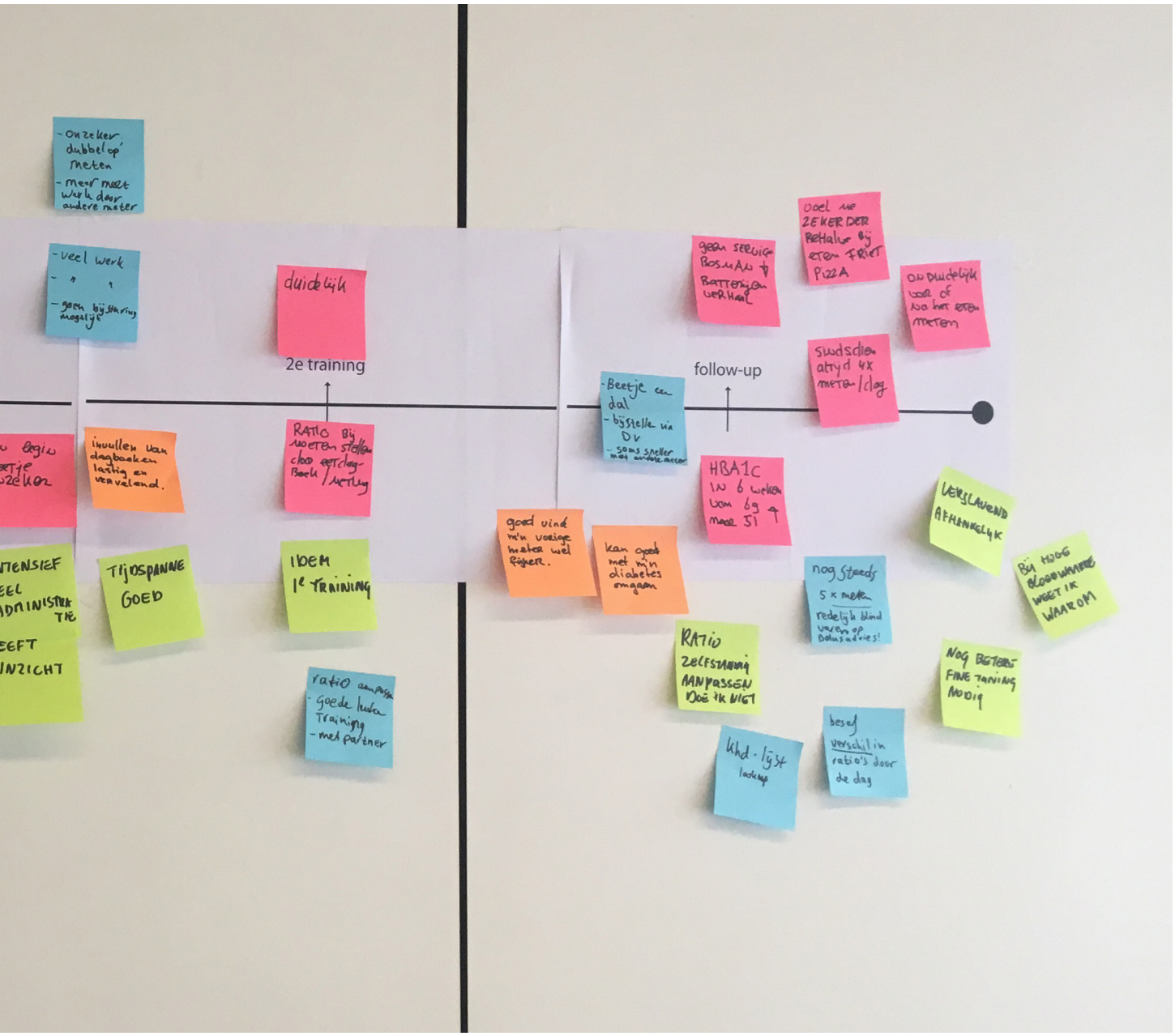


Fig. 26: Result of the timelin exercise: from deciding to joni the carb training to the present

Picture of the explorative session: talking about the timeline

7.3 Insights from experience experts

Below the insights gained during the explorative session are summarized. The sources of the quotes can be found in the clusters in Appendix A.

Counting carbohydrates: image and approach
Counting carbs has a very bad image because it is associated with diet and people don't want to be limited in what they can eat. However, this is not what carb counting is. In fact it only helps people with diabetes to still be able to eat whatever they want. It is seen as the most difficult part of the therapy because you can make mistakes with it. When starting with counting carbs it does take up a lot of time however during the session it was mentioned that after 2 years it is not hard any more. It has become habit, just like checking your blood glucose levels.

"Counting carbs didn't turn out to be so difficult"

"After awhile you know a lot by heart, it is the exceptions that make things difficult."

The way how people approach counting carbs was very different amongst the participants. Two of them valued a precise approach; they weigh their portions, use apps and one of them even brings a list with carb properties with him in his bag. The other two couldn't bother as much to be precise. They made estimations based on their previous experiences and took for granted that they would have to adjust their glucose levels with extra insulin after a meal every now and then.

Different apps are being used but in general they don't all feel as trustworthy as for example a list from the hospital or a book from the Voedingscentrum.

Meter: less worries
The meter is greatly appreciated because it takes away the burden of calculating and it makes people more secure about their self-management. The fact that it gives advice based on their personal settings makes it feel trustworthy and it takes away worries of injecting the wrong amounts of insulin (Sleeswijk Visser, Hoog 2016).

"The meter has made me feel more secure about diabetes"

Someone mentioned that the confidence you gain by using the meter can also be a downside because it makes you "addictingly dependent" of it. In a situation in which the meter can not be used someone would then feel insecure about self-managing diabetes.

"If I don't measure enough I start to feel insecure about my blood glucose values"

Training
Everyone valued the new knowledge retrieved via the training. Education is key for feeling more secure; understanding why something happens enables people to put the situation in perspective, then it is not so bad that it happens. Understanding also caused motivation; people got curious to how things work and started experimenting with different carbs and playing with personal settings.

"I learned a lot during the trainings, they really were an eye-opener for me"

"When something goes wrong now, I don't panic because I know what caused it."

Even more insight into growth and development would be appreciated. Now people still rely on expert knowledge to assess whether they are improving. If the growth could be presented clearly so people could apprehend it this would only add to the confidence in self-management.

Other insights, beyond the scope of this project
Opportunities might lie in how partners are involved, for support and understanding. Right now people might expect their partner to understand and to be considerate, however people also mention that their partner doesn't understand it. This feels contradictory and might be a lead to an interesting opportunity.

"For my partner everything concerning diabetes is a mystery"

"I find it important that my partner is aware of what diabetes means"

Contact with peers is very much appreciated. Participants even mentioned that they would have wished for another meet-up after the two training sessions, out of curiosity how the others were doing. There could be something in a buddy-system during the first few weeks or months of the therapy.

"I really appreciated getting into contact with other people with diabetes"

The collage on the right is a collecion of photos send by the participants during the three days upfront of the session.

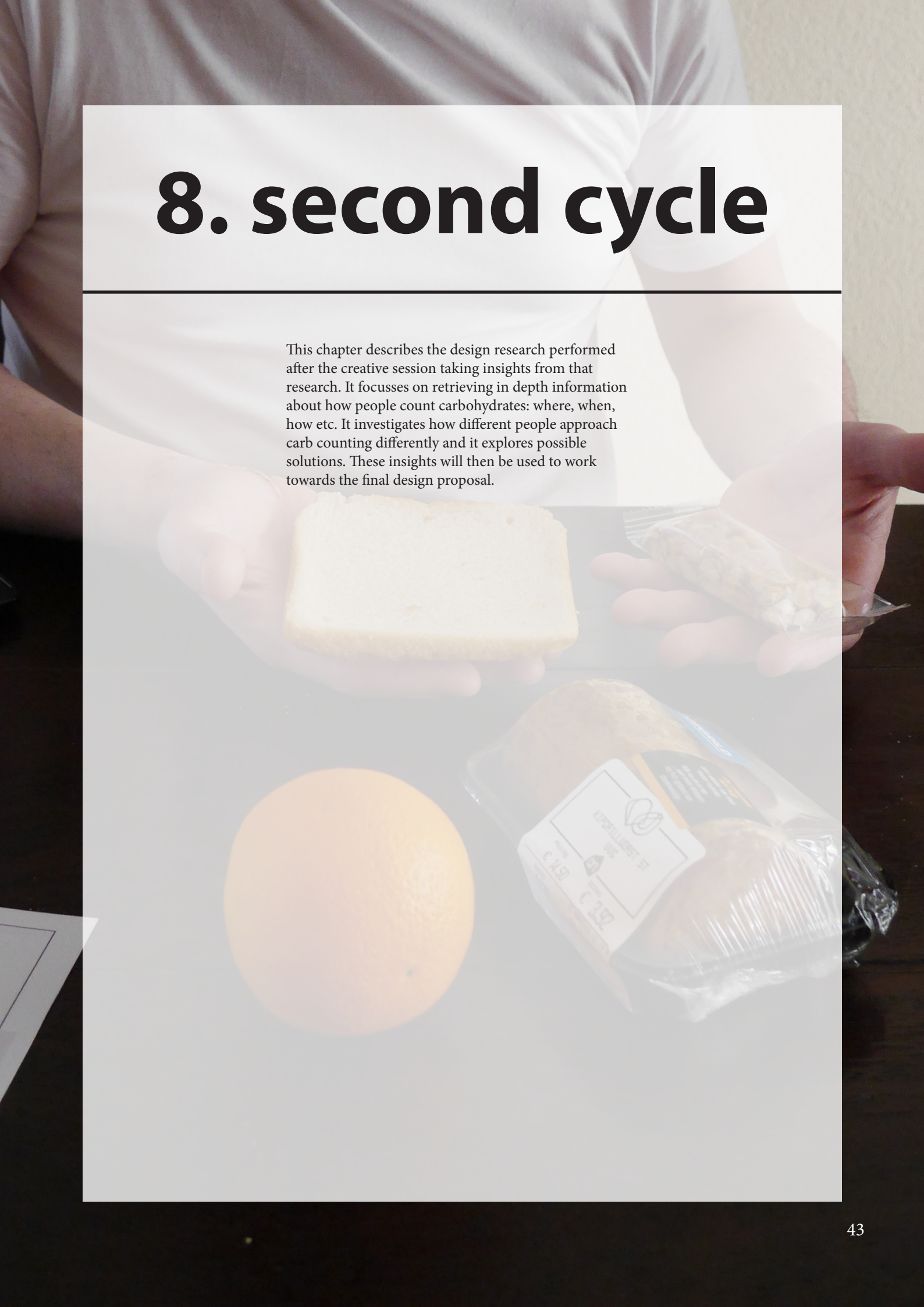

ACCU-CHEK
Aviva Expert
Maandag
6.5
55 g
Annuleer
Bevestigen
Gezondheid
Bolus
Basaal
Actieve insuline 0,0 U
Menu
Bolus
Bolus bevestigen
Insuline injecteren
49 U
13.1
BIO
Mars
SNICKERS
MODE
TARE
810 g
Valeurs nutritionnelles moyennes/Gemiddelde voedingswaarde/ Información nutricional/Valores nutricionais médios | ø/100g | ø/150g* | %RI
Energie/energie/Valor energético/Energia | 615kJ/146kcal | 1229kJ/293kcal | 15%
Matières grasses/vetten/Grasas/Lípidos | 5,0g | 10,0g | 14%
dont acides gras saturés/waarvan verzadigde vetzuren/ de las cuales, saturadas/dos quais saturados | 0,9g | 1,8g | 9%
Glucides/koolhydraten/Hidratos de carbono/Hidratos de carbono | 21,5g | 43,0g | 17%
dont sucres/waarvan suikers/de los cuales, azúcares/ dos quais açúcares | 1,3g | 2,6g | 3%
Protéines/eiwitten/Proteínas/Proteínas | 2,5g | 5,0g | 10%
Sel/zout/Sal/Sal | 0,50g | 1,00g | 17%
RI (reference intake) = Apport de Référence pour un adulte-type (8400kJ/2000kcal) (AR)/Referentie-inname van een gemiddelde volwassene (8400kJ/2000kcal)/Ingesta de referencia de un adulto medio (8400kJ/2000kcal)/Dose de referência para um adulto médio (8400kJ/2000kcal) (DR)
*Cet emballage contient 3 portions de 150g de produit préparé au four selon les conseils de préparation./
*Deze verpakking bevat 3 porties van 150 g bereid product in de oven./
Nachos met kaasdip | 100 gr | 32
Chips | 100 gr | 53
Mars, Snickers | stukje | 36
Mayo | portie | 2
4 Sneeën brood met kaas vlees beleg | 64 | 64 | 16/snee
4 Sneeën brood met kaas vlees en 2 zoet beleg | 64 + 11 | 75
Portie muesli + vanille yoghurt + glas melk | 28 + 18 + 9 | 55
1 pannekoek | 20/stuk.

7.4 Conclusion first cycle

The insights gained in this cycle proved to be a rich source of information showing a variety of possible design directions for this project. Topics discussed such as confidence, the role of a partner and trusworthiness all contain interesting and relevant aspect. However, a therapy such as BolusCal can only be successful if a person is able to determine the right amount of carbs. One thing that the explorative session showed was that education is key for improving confidence in and therefore the execution of diabetes self-management. The general opinion of the participants was that they had learned a lot from the trainings regarding the background of carbs and how to count them but also regarding insulin and diabetes in general. After 1-2 years since these trainings, most of the therapy has been created into new habits. Counting carbs is seen as the most difficult part of the therapy because you easily can make mistakes with that. It costs a lot of time when wanting to be precise. A difference in approach of carb counting was identified: two participants preferred to calculate their carb intake based on weight and carb ratios whereas the other two preferred to make a rough estimation. Interesting to note is that amongst the participants of the session, none of them experienced a great learning curve in counting carbs, other than that they knew their carb intake for particular dishes by heart now. After 1-2 years they still weigh and calculate or estimate. In this session important issues were addressed regarding the entire journey of the therapy. However, to be able to translate current insights to support for carb counting, more in depth information is needed about how people count carbs at home. Insights into the home context and interactions are necessary: when, where, why and how do people count their carb intake? The next cycle will research the details of how people approach carb counting when coming home after the trainings.

8. second cycle

This chapter describes the design research performed after the creative session taking insights from that research. It focusses on retrieving in depth information about how people count carbohydrates: where, when, how etc. It investigates how different people approach carb counting differently and it explores possible solutions. These insights will then be used to work towards the final design proposal.



8.1 Goal

As mentioned in the previous chapter (cycle 1), it seems that at least two different approaches to counting carbohydrates can be distinguished: people who prefer to measure their carb intake as accurately as possible using various tools and people who prefer to make a rough estimation. The goal of this design research was twofold: first to gain in depth information on how people from these two different groups handle carbohydrate counting at home. Secondly this case was designed to explore possible design solutions how to support people in counting carbohydrates.

8.2 Convenience vs. Accuracy

What differentiates people from these two different groups is firstly the mentality of wanting to be as accurate as possible versus being able to trust on a rough estimation. There are people who take it very seriously and want to be sure that what they eat equals the amount of insulin they inject. The other group includes people who don't mind being less accurate, they can still feel secure about their diabetes using rough estimations and adjust when necessary afterwards. Secondly, people differ in the time and effort that they put into counting carbohydrates. For one group it is more important to be accurate than to be quick, whereas for other people it is more important to be quick than accurate.

If you take these two groups to the extreme you could draw a picture of what the consequences of the two different approaches are. On the one hand people are strict and accurate in their carb counting and probably have consistent blood glucose levels, however they depend on the tools they need for their calculation. When taking those tools away they would feel less secure about their carb count meaning that they probably are not very flexible in what, when and where they eat. On the other hand you have people who are confident and independent of tools and therefore can live very flexibly, but who probably are less accurate and less consistent in their blood glucose levels. When looking at these two extremes, somewhere in the middle there could be an approach suitable for a wide range of people: creating freedom while still taking counting carbs seriously and being accurate enough in an estimation. This was put to the test.

Two different cases were designed in which people who normally prefer to be precise would now be asked to estimate and the other way around. More details of both cases will be explained on the next page. The idea behind this design research is to confront people with one of the two different approaches with the other approach. In this way people are being stimulated to try a new approach that could actually be effective too. Also it is intended to make clear what the reasons are for people using their own approach, they might be provoked to defend what they do currently. In this way the research explores what truly motivates these two groups and whether these two groups can learn from each other to create a new mixed approach.

8.3 Method

Two different explorative 4-day cases were executed at the homes of people with diabetes from the two different groups: the Accuracy case and the Estimation case. The participants were divided beforehand into whether they are "calculators" or "estimators", based on their current approach to carbohydrate counting. The two different groups were given different cases involving different exercises. For the Estimation case booklets were made containing exercises with estimating. The Accuracy case were given a special weighing scale and a booklet containing an exercise with the scale (Appendix B&C).

The cases were kicked off with a face to face qualitative interview diving into how people count their carbohydrates now. The cases were completed with a face to face reflection session. All interviews were recorded, transcribed (Appendix E), so quotes could be retrieved and used for further analysis. Participants were asked to send regular updates so progress could be managed.

Fig. 27: Setup of user test material

In total 5 people with diabetes participated in this case study, 3 people who prefer to measure and be accurate and 2 people who make rough estimations. The participants were selected from the patient database of Roche DC. Since the research focuses on people who are still quite new to carbohydrate counting so who can still use extra support to master the skill, one requirement for recruiting participants was that they have participated in the BolusCal training somewhere in the past 6 months. Another requirement was that people eat carbohydrates and still use the meter for a bolus advice based on their carbohydrate intake.

Since participants of the Accuracy case were asked to use the scale at diner time, a dietician was asked to check the outcome of the participants as to eliminate the risk of causing negative effects on people's therapy. She was constantly available to the participants to ask whether she could check their calcuations.

The Estimation case
Hypothesis: Through using real food, visuals and haptics, people's skills in estimating carbohydrates can be improved.

The idea behind this case study was for people, who usually try to weigh and calculate their carbohydrates, to now let them experience making estimations by giving them exercises. They were asked to estimate carbohydrates based on feeling the weight or estimating with their eyes. Three exercises were created:

1. Estimating the weight of food products
2. Estimating the carb ratio of food product
3. Estimating how the carb content of different food products compare to each others

For more details on the exercise see Appendix B.

By taking away tools it can be investigated whether people have become dependent of them; do they feel insecure about their own estimation? It can also be investigated how well people actually are at estimating and explored how this skill of estimating could be enhanced.

The Accuracy case
Hypothesis: A smart weighing scale that makes it easier to make a more accurate approximation of the carbohydrate intake would help and be used.

Their exercise consisted of first creating a special scale distribution for food products based on the label of that product (carb weight per 100 grams). Next these scale distributions could be put on the weighing scale so the actual carb weight could be read rather than the food weight. For more details on this exercise see Appendix C.

This case was designed to let people who usually apply the quick and rough method use several tools to accurately calculate the total amount of carbohydrates in their diner. The idea behind this case is that by forcing them to be accurate they could check if their estimation skills are good or not and to make them think about why they don't try to be more accurate and why they don't want to use extra tools. Also the idea of a smart scale could be tested, would it be convenient enough to start becoming more accurate?

Fig. 28 One of the participants of the Estimation Case executing the weight exercise

Fig. 29 One of the participants of the Accuracy Case holding up the weighing scale

Fig. 30: Demonstration of the estimating weight exercise

Fig. 31: Demonstration of the carb ratio estimation exercise

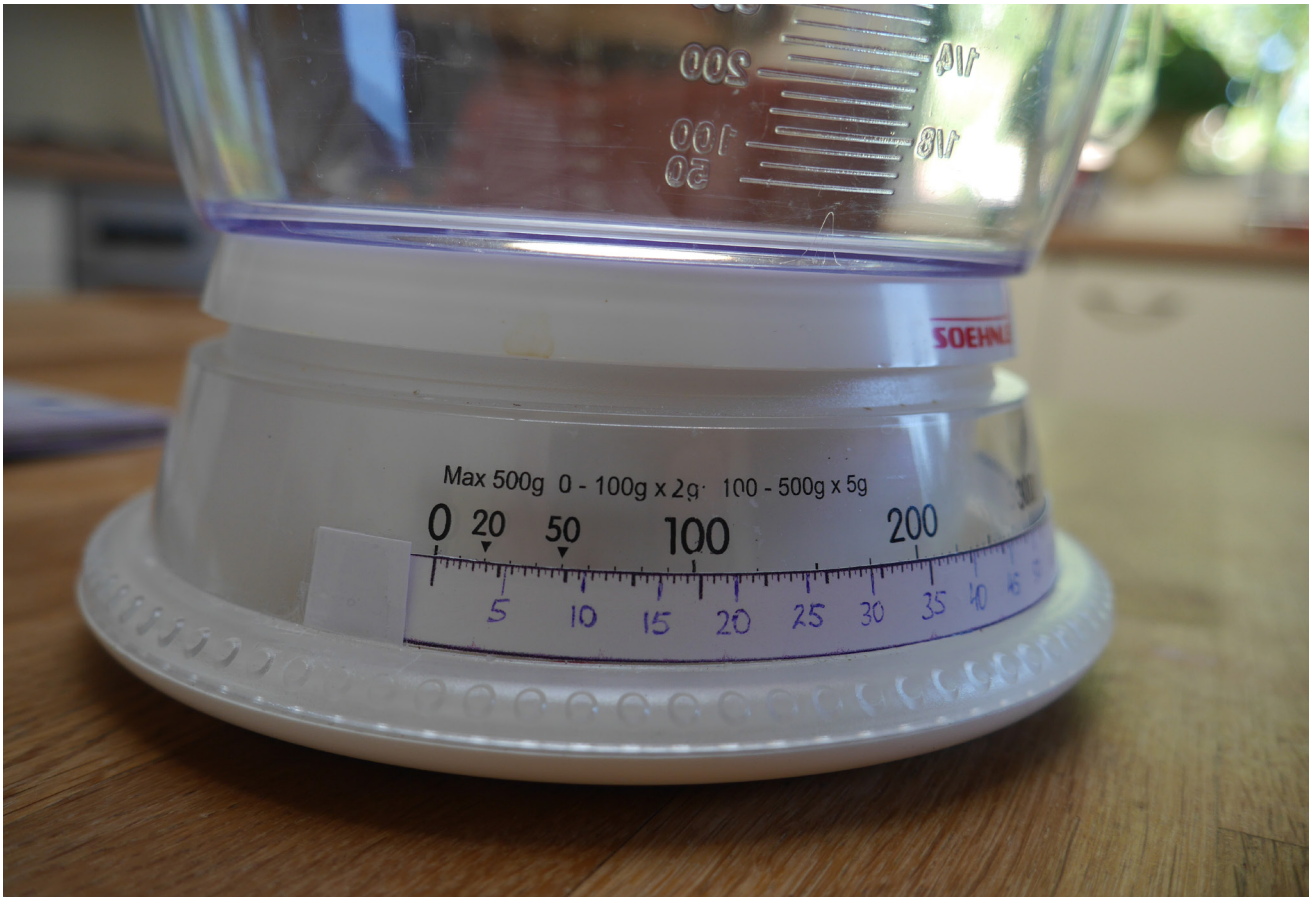


Fig. 32: Intended use of the weighing scale, with completed distribution rulers

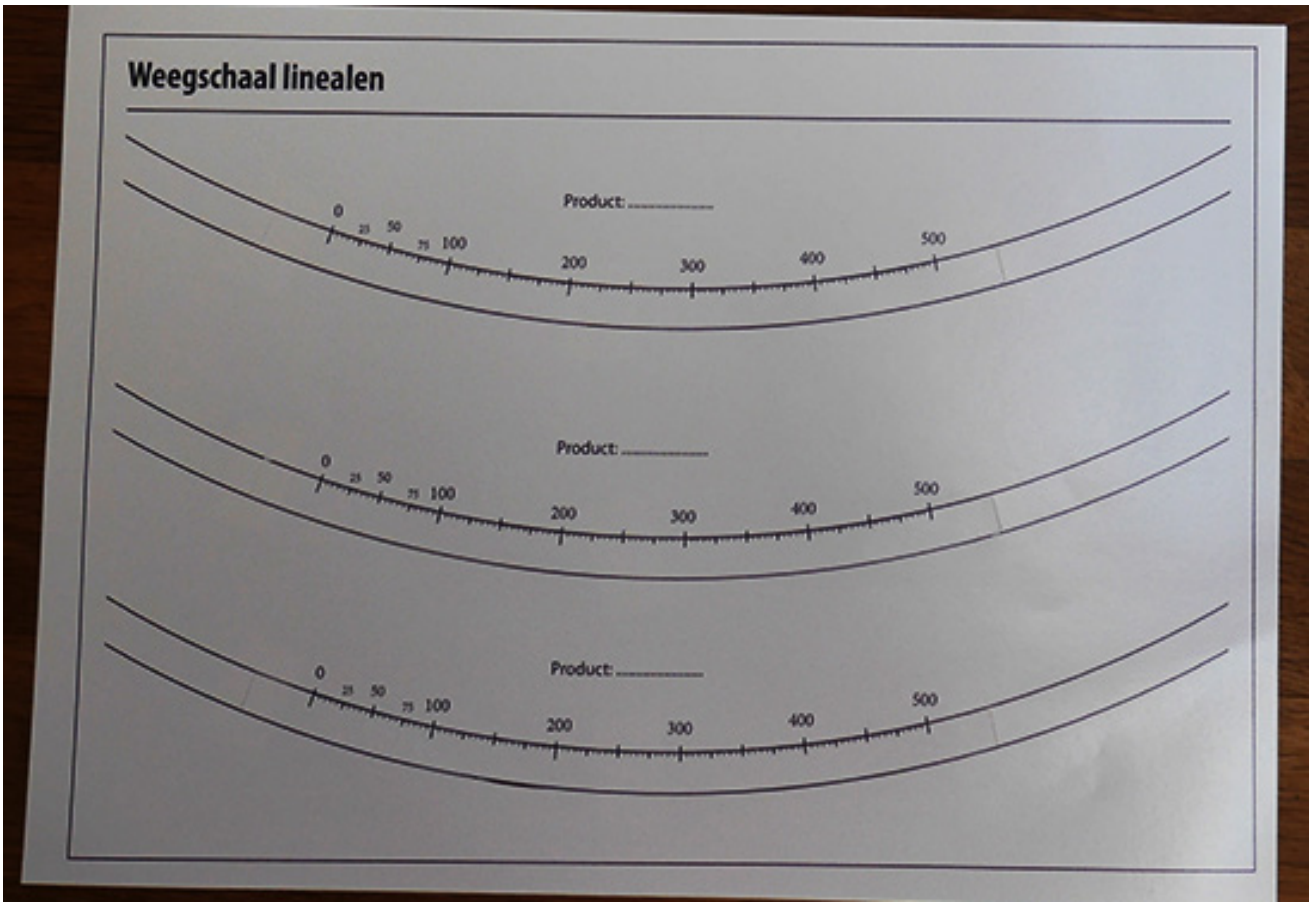


Fig. 33: Picture showing the distribution rulers how they were handed out to the participants

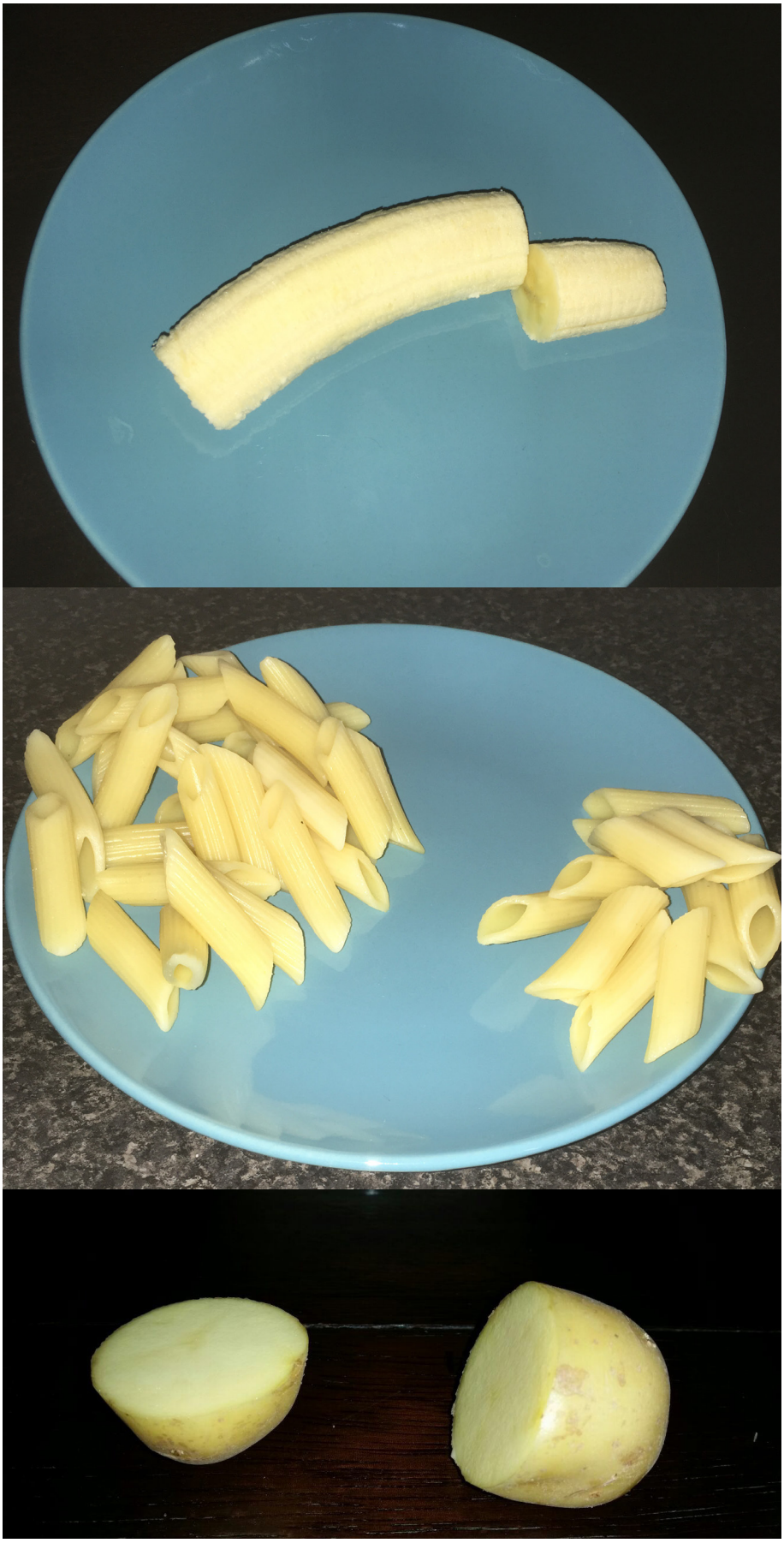


Fig. 34: Carb distribution exercises performed by participants of the Estimation Case

Fig. 35: Weight exercises performed by participants of the Estimation Case

8.4 Insights on determining carbs in practice

Counting carbs in practice
In theory, carb counting is most practically done with unprepared ingredients. In this way the ingredients are still raw, which is convenient because the food label often only presents the carb property for raw products. Also, the ingredients are still separate which makes it possible to weigh how much of every ingredient is about to be eaten. However, in practice most participants preferred to count the carbohydrates when serving the plates at the table. In this way you can be sure that what you put on your plate is what you are going to eat and therefore is the amount you need to asses for carbs. Also, in practice most participants found cooking already a hectic task, especially when having kids around who need to be somewhere at a certain time. This causes weighing and calculating to be too much work at moments where people are busy with other cognitive tasks. It is a lot easier to weigh at the table when everyone is sitting down.

"When the children are here than I don't take the time to accurately calculate my carb intake" (Appendix E, quote 1.1.7)

"I weigh what I put on my plate, so I know exactly what I eat" (Appendix E, quote 1.3.5)

"The evenings are always very hectic here so I don't have time for weighing and calculating." (Appendix E, quote 2.2.2)

Need for trustworthy, central source of carb properties
All participants used multiple tools to find the carb properties of their ingredients. The tools varied from apps, food labels, websites, lists of the hospital, books and personal lists. The reason for using multiple sources of information is because there is not one source that contains all information. Also, sometimes there are differences between what these sources say. This might be due to that an app uses information of it's users and is therefore prone to contain errors or due to using slightly different products. The participants of the Estimating case had experienced these differences especially in what the food label presented and what their app would suggest. When having to choose all would trust the food label above another source.

"It turned out there was a big difference between my app and the food label." (Appendix XX, quote 2.1.3)

"It did made me lose trust in the app" (Appendix XX, quote 2.4.5)

"I want something that can easily present me with relevant and accurate carb information" (Appendix XX, quote 2.3.4)

Time plays an essential role in whether a tool is used or not
The main reason for the Accuracy group not to use tools for being more accurate in carb counting is the issue of time and being impatient. When wanting to be precise means spending time on retrieving specific product information, weighing and converting the numbers which for many people takes up too much time. Interesting is that even a participant who has the time to do all those things, he still doesn't do them. He finds it so cumbersome that they are not even worth his time.

"For me the distribution rulers were too laborious" (Appendix E, quote 2.2.2)

"It't not that I don't have the time, it is more a form of laziness, not wanting to think about it all the time" (Appendix E, quote 1.5.17)

"It was the combination of calculating and recording everything that made it too much work for me, and then you don't really know, so you just do something" (Appendix E, quote 2.2.9)

"The more actions is takes me, the less likely I wil do it." (Appendix E, quote 1.5.7)

"If this were to go automatic then I would really like such a scale" (Appendix E, quote 2.5.1)

Short-term challenge and reality check
Participants of both cases responded positively to the cases because it had forced them to focus heavily on carb counting for 4 days, giving them a short-term challenge and therefore motivating to make the effort. Carb counting can be an abstract task because you are never really sure whether you are right and even when you are right your blood glucose levels might become too high or low because of other reasons than the wrong carb estimation. Doing these tasks gave them a sense of how well they actually are at counting carbs; an insight which all valued.

"Once you get started, you get curious to all kinds of things and how many carbs something would contain." (Appendix E, quote 2.4.2)

Carb education

Doing these tasks stimulated the participants to dive into determining the carb content again, just like when they started with applying carb counting theory (3-6 months ago). Especially researching the carb properties was intriguing because it is not something you can reason. Some products contain more carbs than you would expect; it is a property that is difficult to categorize based on looks or type of food and it is therefore difficult to recognize. Most frequently eaten food will be memorized over time, but every new product should be initially looked up. Interestingly, onely one person mentioned the fact that drinks can also contain a lot of carbs, yet he never asked for a bolus advice based on his drinks.

"Estimating the carb ratio will remain difficult because you will always need the specific knowledge of that product, it is not something you can reason" (Appendix E, quote 2.1.2)

"I want to know how everything with carbs work" (Appendix E, quote 2.2.10)

"Drinks are difficult for me, I never count them as carbs or inject insulin for it" (Appendix E, quote 2.4.1)

Visuals versus haptics

Based on the 3 different tasks that the participants of the Estimation case had to execute, it seems that estimating a product's weight comes more natural based on visual properties rather than tactile properties. Even though you might think that feeling a product has a more natural link with weight it seemed that the participants were better trained at assessing weight based on volume. This might have to do with the fact that feeling the weight of a product is a known difficult thing to do. This has to do with the size-weight illusion which has been researched a lot (Flanagan and Beltzner 2000). It seems that the smaller of two products with equal weight is judged to be heavier when it is lifted.

It might also have to do with unconsciously building experience in judging by the eye. Every time you eat or drink you look at it, creating a feeling for how 200 grams of vegetables or 150 grams of pasta look like.

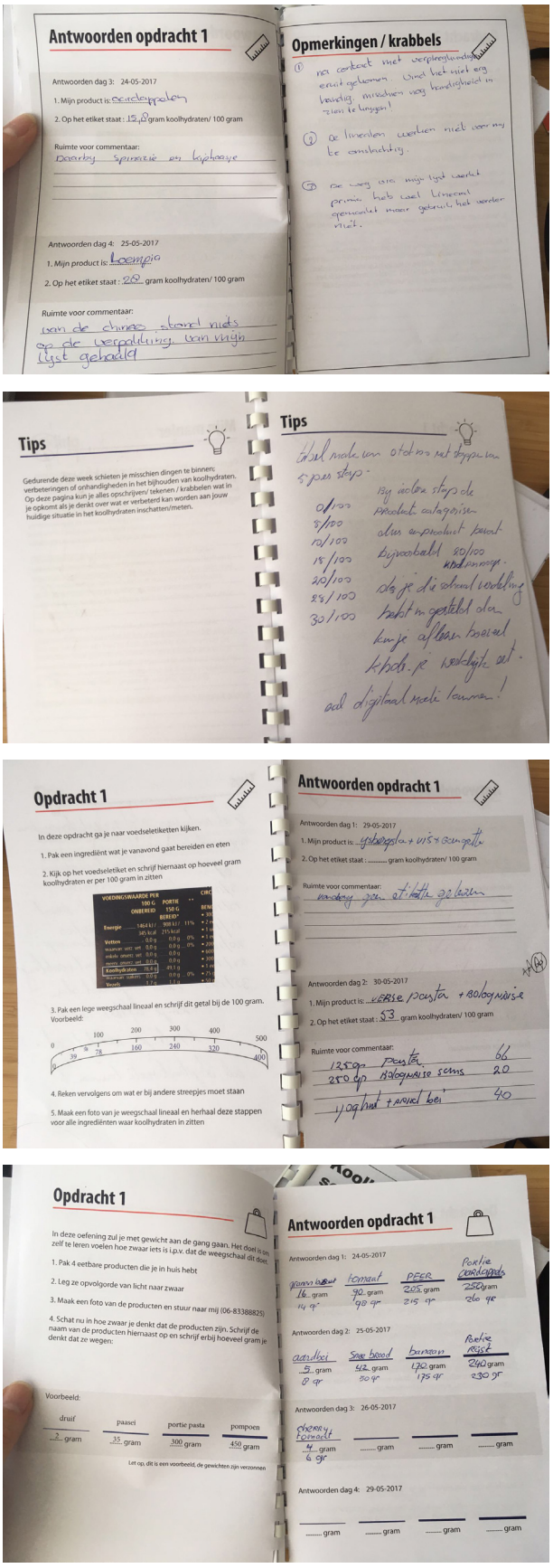


Fig. 36: Photos showing returned booklets of different participants

"**The exercises taught me a lot, it gave me many insights." (Appendix E, quote 2.4.1)**

" That is the great thing of this exercise, it becomes really visual." (Appendix E, quote 2.4.2)

"I discovered that my feeling is often correct, that gives me a lot of confidence" (Appendix E, quote 2.3.2)

"These exercises would have helped me in raising awareness of carbs in a very short time." (Appendix E, quote 2.1.7)

"It is difficult to assess weight by sight as well as by feeling." (Appendix E, 2.1.1)

"If you train a lot on this than I do think that they eye will become better trained at determining amount but also carbs." (Appendix E, 2.4.7)

Other approaches to determining carb content
The participants of both cases weren't as divided in their approach as described beforehand. This was to be expected; in practice people will be a mixture of approaches. People are too multifacetted to be placed in specific categories (Bandura, 1998). This, however did not cause the cases to be unsuccessful. In fact, it showed that a group can be added to the accuracy-convenience division: the group of people that find the precise approach too complicated but who cannot rely on their skills to make an estimation (see fig. XX). This group is left with a tool such as a list with common foods in common quantities, telling them how many carbs they contain. The risk is that they are completely dependent on a list of common foods that might not match their own food or might not match their own quantities. It is important to highlight this group because they are currently underexposed in the BolusCal therapy. Other than their healthcare professional, the program does nothing for them to support them in counting carbohydrates, which might be a missed opportunity.

limitation of this study
The exercises of the Estimation case contained pre-selected foods. This caused that some people had a difficult time estimating the carbs because they would never eat it themselves. The Accuracy case was meant to make calculating easier, which it did. However, through doing that it made other actions more difficult: creating the scale distributions was perceived as difficult. Therefore, there is a limit in the restults to how a smart scale was looked upon.

Estimating	Calculating	Guessing
People who prefer being quick over being accurate. They trust on their knowledge of products and their experiences. Taking into account: type of food/drink, size of portion and comparison of carbs in other food/ drinks they estimate the carb content	People who prefer being accurate overbeing quick. They don't trust on their knowledge, only on their previously positive experiences. They use a weighing scale, calculator, food labels, carb books and mobile applications to get to a carb content.	People who prefer being quick over being accurate. However, they don't have the skills, knowledge or trust in their own skills make an estimation. Based on their insulin amounts they gues the amount of carbs and build experiences of guessing carbs on that.

Fig. 37: Diagram explaining three different approaches to determining your carb intake

8.5 Conclusion second cycle

This design research gave insights in how different people approach counting carbs differently and they could be supported accordingly. It also showed that the participants liked getting better at counting carbs, no matter what approach they were using. By gaining insights in carb counting they felt more secure in making estimations. The tasks gave them the support to try to improve themselves and the challenge of wanting to do well motivated them to do even more in some cases. When it came to making an estimation in the different tasks, the participants seemed better at and felt more comfortable with assessing weight based on assessing the volume rather than based on how heavy something felt.

Another important insight is that counting carbs often takes place at the table when everyone else is ready to eat and the food is ready to be served. The concept will focus on this context while taking into account that the right moment plays an important issue in whether a tool will be used or not. Even if people have the time they don't always want to use it for carb counting. This might mean that an extra motivating aspect in the design could be appropriate.

In the next chapter the third design cycle will be presented, that continues with the insights gained from this research and will investigate how people can be trained in estimating carbs with the use of a product.

9. Third cycle

The previous chapter showed that people might be better at determining an amount of a product based on how it looks rather than how it feels, even if it is the weight that has to be determined. It seemed that participants were quite comfortable with determining amount and weight based on assessing volume by the eye. This phase of the project was dedicated to exploring this insight further while translating it to a product. A first attempt was made to embody ideas and outcomes of the previous iterations in a concept which then evolved in a second concept. The goal of both concepts was to gain insights into how a training could be embodied in a product that adds to the carb count knowledge and skills of the user, making him independent and flexible. This cycle investigates the connection between feeling weight and seeing weight; whether estimating weight in grams could be trained via first estimating volume.

A paper prototype was made of this concept which was explored by healthy people. The insights retrieved through the paper prototype will be used to create the final design.

9.1 Goal

This part of the process was dedicated to embodying carb estimation training into a product through linking weight and volume. This concept should enhance people's knowledge and skills in estimating carb content flexibily, independently and confidently.

9.2 Volume and weight

Since people had difficulties in assessing the weight of products a first idea was a serving spoon that can weigh. This comes from the vision that you could train people in feeling the weight by using a given that is familiar to them. When scooping food on a plate many people use a serving spoon and are quite consistent in how many spoons they serve themselves. Many hospitals use this to make carb counting more convenient for their patients. They provide them with a form that lists how many grams of carbs one spoon of an ingredient contains (see fig. 13 p. 22). This is an easy tool because people only have to think about how many spoons they serve themselves and multiply the amount of carbs to reach a total. It also uses the connection between volume and weight however it does assume that everyone uses the same serving spoon, giving people a false sense of accuracy. The idea is to exploit the concept of going from volume to the belonging weight even further by designing a serving spoon that can weigh the food on it. In this way the user is trained in connecting volume to an accurate weight for every ingredient.

During the evaluation of this idea a few disadvantages came to the surface:

1. If people are going to be trained in connecting the visual amount to the weight amount why not do this with the total amount instead of the amount that fits the spoon? Connecting the weight to the volume of a regular portion is more useful than the volume of part of a portion.

2. In this idea people are trained at determining weight by feeling it, however what they feel is the weight of the food plus the weight of the spoon. Since you can not standardize the weight of the spoon this training might train people a false skill.

3. Also it might not be desirable to train people in assessing the weight of food by holding the food, since you rarely hold your food in your hand. Apart from sandwiches and snacks, more often we eat from a plate.

4. This idea tries to train people in determining weight by holding it, something that people had difficulty with during cycle 2. It might be better to exploit skills we already are trained at rather than improving skills we are weak at. Also, the size-weight illusion will stay to be a difficult phenomenon in training weight skills.

These objections were reason for a new idea: a product that trains people in estimating the amount of carbs in grams through training only the eye. The product should do the things for us that we are not good at but it should train us in the knowledge we need to make a carb estimation away from the product.

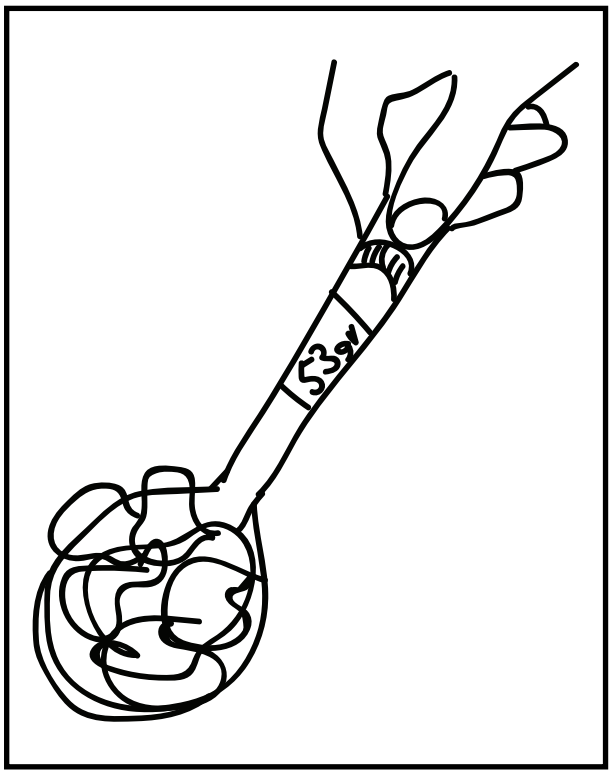


Fig. 38: Sketch of the weighing spoon

9.3 Plate scale

A different idea was a scale that can weigh at two different positions enabling the user to weigh the total amount of food and the total amount of carbs. This was derived from the vision that people can be trained in improving their carb estimating skills by visually representing the carbs of different ingredients. Two exercises can be performed on this scale: entering carb ratios into the scale (see fig. 39) and estimating carbs using two different scales (see fig. 40).

First exercise (upper picture)
The user is asked to turn the outer wheel to select the carb ratio for a specific food product. By making this into a physical action, enriching the interaction (Wensveen, 2004) people might be more likely to remember where different foods are on the scale.

Fig. 39: Picture showing a participant trying to set the carb ratio using the ring

Second exercise (lower picture)
The user is asked to scoop food on the plate (printed pictures of food) and then to think about how much of this food would be carbs. This amount is subsequently slid over to the other side of the scale. If the estimated volume of the carbs in the food is estimated right then the weighed amount of carbs is also right. This direct connection between volume and weight is what will enable the user to be trained at estimating weight through estimating volume. The idea is to train people in 'seeing' carbohydrates in the food products, as an intermediary step to get to carbs in grams.

Fig. 40: Picture showing a participant playing with the food distribution on the two parts of the plate

9.4 Main insights on testing paper prototype

The paper prototype of the training was explained and given to several healthy people. Through acting out and discussing the concept several important insights were discovered.

Scope for training
For practical reasons the training scale was designed to be used for diner, since this is the meal which people struggle with most and therefore is the meal that is focussed on by hospitals and people with diabetes. However, the scale should provide tools to train people with everything they eat and drink. Interestingly right now the existing BolusCal training puts a great focus on food compared to drinks whereas drinks can easily contribute just as greatly to the blood sugar levels compared to some foods. The scale should therefore make it very clear that everything you eat and drink contributes to a rise in blood sugar levels and it should stimulate people to use the scale and train themselves in everything they eat and drink: breakfast, lunch, diner, snacks and drinks.

"What type of food or drink can I use this scale for?"

Connecting database and training
Right now the scale incorporates the training and needs a database to do so. Filling the database by the user himself is important because it makes the database personal and trustworthy. However, it would be more in line with the concept and be a more elegant solution if the database was integrated in the training while being a tool on itself as well. The database could be the result of the training and become the backup tool when being away from home and a carb estimation has to be made.

"So I can use all information from an app but I first have to fill the database of the entire app? That might be a lot of work when I want to eat."

Carb representation in food
By using the weight of the food to weigh the amount of carbs there is the risk that people might get confused by the representation of carbs in food. Strictly speaking this is not reality so it must be investigated further if this representation is a useful tool or a confusing method. However, based on the test with the paper prototype the visual image of representing carbs in the food really triggered people to think and play with the food and the proportions, exactly as intended. However, the next step is for people to learn to connect actual weight in grams to their estimated proportions. People have to be provided with more information and feedback to achieve this.

"I think it is this proportion [dividing the food on the plate]" "No, it is much more! I think it is this [redividing the food]"

Growth curve
To motivate the user to use the scale and fill the database, feedback should be provided of the growth he makes. It could be made insightful in how well the user is in estimating the amount of carbs. Right now, people already experienced some sort of playful element, this could be exploited even further to motivate the user.

"It is almost like a game, I feel motivated to do well"

Training is the essence
By using the training scale the user will become more skilled in estimating carbs in food on his own. This means the training scale will make itself redundant over time. It should become clear how the use and lifetime of this product is intended.

Visual representation of carb ratios
It was mentioned that visualizing the carb ratios in one visual would be very insightful. It would enable different products to be compared, connected and therefore remembered more easily. The outer ring of the scale serves as an interesting opportunity for this.

"How do I know where the potatoes are on this ring?"

9.5 Conclusion third cycle

This third iteration investigated how a training could be embodied in a product. The decision was made to focus on the specific learning strategy to estimate carbs weight through assessing carb colume. Through a paper prototype and acting out, several points were highlighted that would need change or improvement. For the final design it should be clear who this training scale is intended for and when and where it is supposed to be used.

10. Fourth cycle

This cycle continues with the paper prototype introduced in the previous cycle. The insights gained through that study are integrated in a new version of the concept. However, no decision could yet be made as to whether the visual image of carbs in food would work effectively of confusingly. To answer that and other interaction questions, a working prototype is made and tested for 6 days at the homes of three participants. The results of this user test will be used as the last research to finish the final design proposal.

10.1 Goal

An interactive prototype was created to test and evaluate the use and function of a training scale. Due to practical reasons not everything of this concept could be created so the choice was made to focus on the interaction between a training scale and its user. In this way something could be said regarding people's first reaction to such a product, whether they understood the exercise, whether the exercise helps them (compared to how they do it now) and whether they appreciate its goal.

10.2 What

The core of this concept was tested through this user test.

Main research question: does the visual image of carbs in food support people in making estimations?

To answer this, the working prototype was designed with the following sub-questions in mind:

1. How do people react to the training scale in its current format?
2. Do people understand how to use the training scale?
3. Does the training scale help them in estimating carbs (compared to their current situation)?
4. Is something missing that could possibly help people even more in their ability to estimate carbs?

To answer these questions the prototype should have several functions. For one it should allows for the exercise to take place which is estimating carbs based on redividing food over a plate. This means that it should be able to weigh on two separate places and calculate with a carb ratio. It should also give proper feedback to guide the user to make the right estimation. To let the user understand what he is supposed to do the prototype should give proper feedforward. Lastly, since interaction is the main research objective of this study it is important that this prototype can be used in the desired context: at the table during dinner. This means that multiple foods should be able to be placed on a plate: a new food should be placed without removing the previous. Subsequently, the sum should be calculated of all carbs.

Due to practical considerations, some desired functionalities could not be integrated in this prototype:

1. Data storage: the training scale does not store data of carb ratios or portions sizes. This means that the participant has to enter the carb ratio every time he wants to use the scale, even if that specific food has already been entered.

2. Mobile app: the training scale is not connected to a mobile application yet. This means that the participant can not yet benefit from stored data as a back-up when away from home. It also means that the user cannot create mixed meals yet on his application making it still impossible to work with mixed meals on the training scale.

3. No interactive screen: It does not work with a screen to present new data on the ring around the plate. This means that the participant is not yet presented with feedback of his personal drinks and foods when entered into the training scale. Rather he is presented with 5 fixed example products on the outer ring. It also means that no distinguish is made yet between the different modi of the ring: breakfast, lunch, dinner, snacks, and drinks.

10.3 Method

The prototype is placed at the home of 3 participants for 6 days. One participant was selected based on his experience with counting carbs (he has been counting his carbs since octobre), giving him the ability to compare the training scale to how he handled it after having attended the training sessions in the hospital. He was also one of the participants of the Estimation case during cycle 2 meaning that he can compare the prototype to those exercises. The other two participants were selected on having little experience in counting carbs. For one participant it had been 1 month since her participation in the hospital training sessions. The third participant was selected by the hospital in Eindhoven, they have been trying to get her to count her carbs for years but until now she had never been able to do it independently.

When delivering the prototype to the participants, an interview was conducted to understand the participants' current disposition (see appendix XX). Afterwards, the exercise with the prototype would be practiced using up to four different products, depending on the participants' comprehension of the test. The participants were given a handout explaining the prototype's main function (Appendix XX) and leaving plenty of room for them to make any notes. They were given an explanation of the goal of the concept and of the research questions, making them focussed on the intention of the test. Their only assignment was: to use the training scale as much as possible, with as many different products as possible.

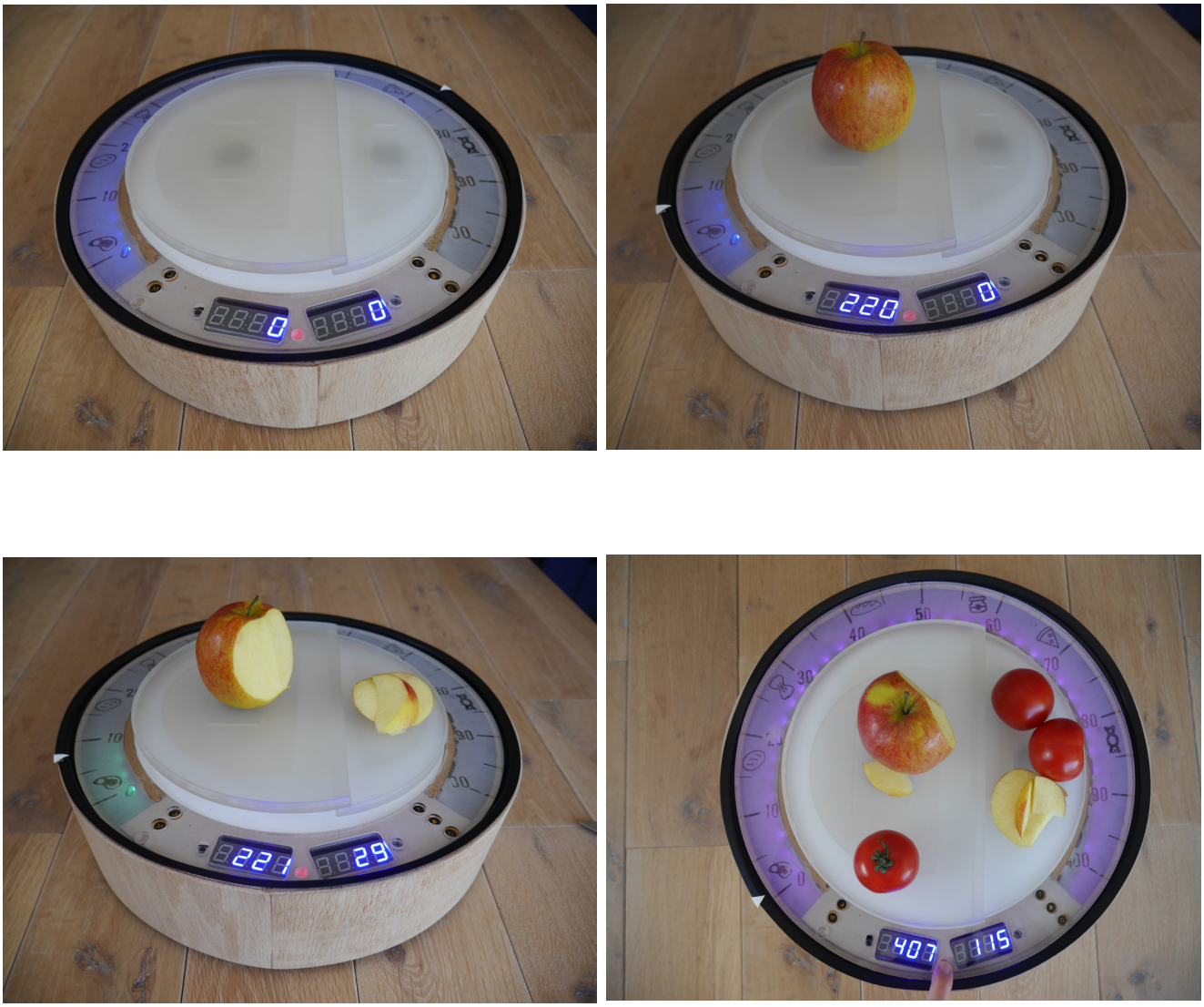


Fig. 41: Pictures showing the different functions of the working prototype: top-left: entering the carb ratio using the outer ring, top-right: Placing a product on the food plate, bottom-left: dividing the apple until the lights blink green, bottom-right: Adding up all ingredients to read the total sums

Picture of the working prototype

10.4 Insights on user test

Visual image
The representation of carbs in food worked very powerfully, people showed reactions of "wow, this much carbs! I didn't know that" or "I didn't expect that!". Doing this exercise greatly contributed to people's awareness of different carb contents in different foods. However, people doubted whether they would learn the numbers by heart when using the scale for a longer amount of time. Due to the short duration of the test and the limitations of the prototype it is difficult to place this insecurity. However, when the participants were asked to recall the amounts of carbs they had estimated using the training scale, they could still remember correctly: "O no I can't remember that, but it was very little [gesturing small amount with the hand], wasn't it something like 5 grams?" (this was correct). This shows that the training had an effect on how this participant remembered the exercise, namely the visual image, which subsequently became a tool to make an estimation of how many grams it had to be.

"I didn't expect it to be this much!" (text message with photo of exercise)

"You see what you are about to eat and how much carbs it contains. That is something that you can't find on a list." (Appendix F, quote 2.2.12)

The ring
The ring is difficult to comprehend and was confusing to all three participants. People get confused with the carbohydrate ratio (... grams of carbs per 100 grams of a product). One of the participants thought that he always had to put 100 grams of a product on the weighing scale, another participant used the carb ratio of her portions instead of per 100 grams and the third participant thought that the amount of carbs she wanted to eat was supposed to be entered in the ring. This confusion might be caused by how participants were previously taught to convert numbers. The hospital taught them to convert ratios so this reasoning might have gotten in the way when entering the ratio in the ring. Also, one participant mentioned that when he first had to enter the ratio using the ring, it was not really difficult any more to make an estimation any more. The exercise might then be too easy. This point can however be rebutted when the training scale would have all its functionalities. Right now, every time the ratio has to first be entered whereas this is not necessary once the scale can store data.

"I was very confused in the beginning" (Appendix F, quote 2.3.1)

The confusion caused by the ring caused two participants to be hesitant and insecure about using the prototype. The user interaction with the ring has to be improved drastically. The user needs more information and more feedback of the numbers on the ring.

The participants did value the visual display of products over this ring. It would make comparing products much easier and insightful. However, no personal products were displayed yet so no deeper insight can be shared concerning this subject.

Feedback
The color of the lights worked very well, people intuitively continued the exercise until the light was green (observed during practicing of the exercise of first interview). In this way, no matter how wrong someone started, they always got to the right amount of carbs. Knowing this beforehand worked reassuring. Also turning the ring was very clear because of the light feedback (going round in a circle). However, one participant felt it would be more natural if the feedback of the red/green light would be placed near the screen which also feeds back the grams, now she had to focus her attention on two different places.

One of the participants (who already has experience with determining carb contents) really valued the immediate feedback of this scale. Before this scale and the training he also made estimations with his food but the feedback of whether his estimation was correct always came hours later, when checking his blood sugar levels. Over time he learned from these experiences but it took him a lot of time to get a feeling for making estimations. With this scale you get immediate feedback, making the learning process much clearer and faster.

"This tool could support someone with constant feedback of the carbs and total amount. So it would train someone much more quickly and efficiently." (Appendix F, quote 2.2.2)

"I noticed that I wanted to do the exercise right in one go. So it became a little game actually." (Appendix F, quote 2.1.1)

Context
Different products were used varying from diner to snacks and breakfast. There was no unanimous opinion on where the scale would be used in the evening: one participant wanted to use it in the kitchen, because she leaves the food there. Whereas, another participant

would use it at the table, so no extra actions would be required other than doing the exercise. All would want to use the scale with prepared food , however the downside was mentioned that the food might turn cold while doing the exercise. One participant even talked about wanting to take such a scale with her to a restaurant so it would be easier for her to determine carbs then.

"if it could be really small than I could bring it with me to restaurants." (Appendix F, quote 2.2.12)

The format
The participants valued the physical shape of the prototype and the fact that it encorporated their own food. However, the format right now is not ideal because the food first has to be scooped on the plates to do the exercise and then replaced on the plate of which someone intends to eat. This extra action is not desirable for the user interaction. However, it also has to be noticed that people rather not eat from a special "diabetes" plate, especially when having company. The most ideal situation would be when people could use their own plates on the scale so they can put away the scale when eating.

"I wouldn't like to eat from a special plate especially when I have company or when the kids are here." (Appendix F, quote 2.1.5)

Having the scale in the house triggered curiosity to the carb content of different foods. It didn't always trigger the actions to use the scale but it did make people think about it and for example look at the food labels more.

"The scale actually made me more curious to other products." (Appendix F, quote 2.2.5)

Advice
Although this was only mentioned by one participant, it potentially shows an opportunity for a Training Scale. This participant said that she wanted to use the scale the other way around. Instead of putting food on the scale and determining the carb content she would want to enter the amount of carbs she wants to eat and then find out how much of a food she would then be allowed to eat.

Added value
Interestingly, all three participants responded differently to the question of how they would describe the added value of the Training Scale:
1. Raising awareness and knowledge
2. Accuracy and security
3. Relieving and fascilitating

Limitations of this study
It should be taken into account that the training scale is a prototype and had its limitations. First of all it has not been officially tested, meaning that the participants were told that they could not use the scale blindly in their therapy. This might have influenced the participants to take the training scale less seriously. Secondly, it did not work correctly 100% of the time. It could always be reset by the participant, but it might have caused confusion about whether a participant did something wrong. Thirdly, the plate was designed to enable the exercise instead of accommodating the participants with the most user-friendly use-case: it consisted of two separate plates. Fourthly, no app was connected to the Training Scale yet meaning that the participants still had to use their own sources of retrieving the carb ratios. This proved to be more trouble than was anticipated because not all sources of the participants provided them with the ratio per 100 gram which was necessary for the ring. The agreement was made that whenever this happened the participant could skip that particular food or drink.

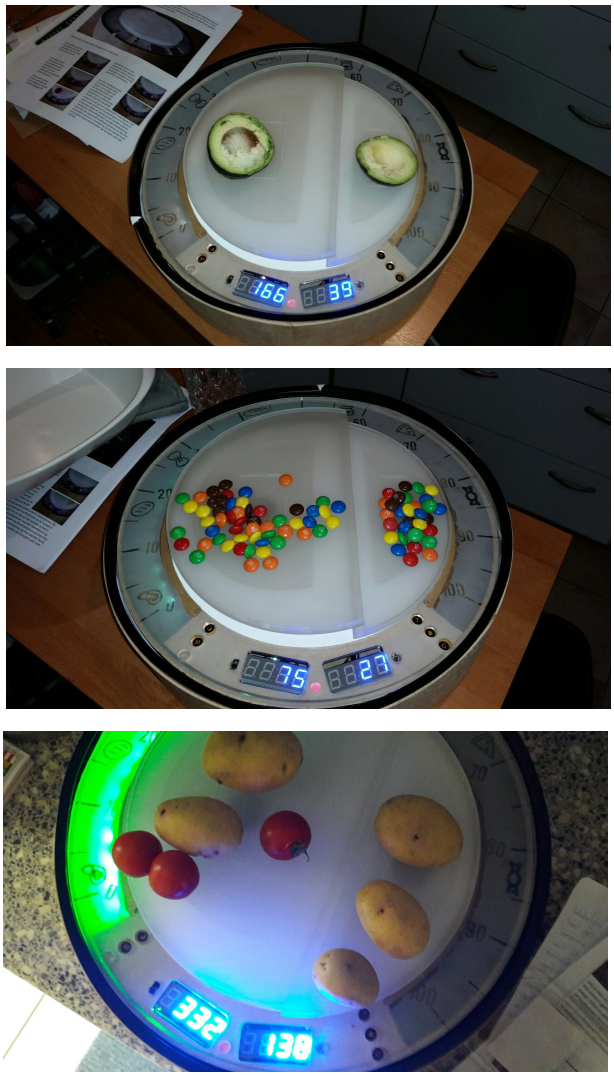


Fig. 42: Pictures that participants sent during their 6 days of testing the prototype

10.5 Conclusion fourth cycle

The working prototype was a great method to test people's reactions to a smart scale in their homes. Letting it spend 6 days with all participants was long enough to include weekend- and working days, giving a broad context for results. Although the prototype did not include all desirable functionalities yet, which occasionaly caused struggles with the participants, the core of the concept could be tested: does the visual image of carbs on food support people in making carb estimations?

In short, the Training Scale was appreciated for its calculating properties, for showing carbs visually in food and for being a fascilitation for learning to determine carb content. The participants struggled with setting the carb ratio of products using the ring (finding the right ratio and physically setting the ring), however they all succeeded in dividing the food over the plates. No consensus was found on when and where the scale would be used. This depended mostly on the composition of the family: if someone was alone he would do it in the kitchen, the table was prefered if there were more people present. Even though the confidence level of the participants was still very low, a first effect of remembering carb content through a visual image was visible.

The Training Scale could be improved by making the ring more user-friendly, by removing all bugs in the system, by connecting the scale to an app so all food properties can be stored and looked up and by designing the format more conveniently. However, based on this test, it seems that the specific visual learning strategy might work and support people.

11. Final design

This chapter describes the final design of this project. It is the proposal for Roche Diabetes Care intended for people in Intensive Insulin Therapy who need training in estimating their carb intake in grams. Within four iterations, research and design have been combined to get to insights of people with diabetes, how they react to the current training program, how they approach carb counting at home and what support could be helpful while learning to count carbs. The proposed design embodies insights gained in all four design research cycles.

11.1 Design research recap

Four cycles of design research have resulted in many insights in the impact of diabetes on people's lives, how people approach diabetes and learning a new skill in counting carbs. Observations of people in the current trainings showed that people need more to apply changes to their lifestyle. It might be that they need more time, more guidance or more incentives to initiate change. Without this extra push, there will be people who can not process or apply all the new knowledge properly and fall back to their previous behavior.

The participants of the BolusCal training from 1-2 years ago agreed that counting carbs has had a positive effect on their blood glucose values, recognizing the benefit of the therapy but most of all emphasizing the relief that the meter takes away a worry by determining the right amount of insulin. However, they differed a lot in their approach in determining carb content: two participants preferred being accurate over convenience whereas the other two participants prefered it the other way around.

This difference in approaches was put to the test in a 5-day study. People who normally use tools to calculate their carb intake were now asked to rely on their estimation skills. People who normally estimate their carb intake by heart were now asked to use tools to determine their carb intake accurately. This test set-up confirmed why people have their personal approach, e.g. time efficiency and the hassle of many actions. However, it also taught the participants to think past their own approach, e.g.if the hassle could be reduced people would take more effort to determine their carb intake more accurately. Number one worry mentioned by the participants was the source for carb ratios. All agreed that the food label on a food product is experienced as most trustworthy but not every product has a food label, e.g. vegetables or food from the market. In those cases the participants turned to various apps, books and lists but these different sources sometime stated contradicting information causing insecurities over their reliability. The test also showed that weight is easier to estimate by looking at the volume rather than by actually feeling the weight.

A design vision for this project was established after this 5 study case. People feel most flexible and confident when they can rely on their own skills to estimate their carb intake wherever they are. However, to achieve this level of confidence and flexibility insecurities caused by lack of knowledge, too difficult subject matter and contradicting information needed to be removed. A tool could be used to train people to this level, using tailored information and close guidance but it should not make people dependent on it.

The ideal outcome of this project would therefore be a tool that trains people to a level of skills and knowledge that gives them the freedom to determine their carb content accurately without using tools.

So a convenient solution had to be found to train people in estimating weight through assessing the volume. Through paper prototyping the idea of a training scale was established: a tool that trains people in connecting food to carb content through visualized carb ratios. A working prototype was made to test such an exercise in practice. It was researched how people would react to a training scale in their homes, what the interaction with the training scale would look like and whether such an exercise would affect people's carb estimation skills.

Design goal
These four iterations worked from the overal perception of the BolusCal therapy to a method to improve diabetes self-management by strengthening carb estimation skills. The design assignment naturally evolved to become a very specific design goal:

Design Goal:

"Design a product that **trains** people with diabetes in Intensive Insulin Therapy in **estimating** their **carb intake** by supporting them with exercises and insights so they can learn to **intuitively** apply their knowledge and skills."

11.2 Training scale

The final design proposal is the Training Scale, a scale that guides the user to the right amount of carbs in their food through an exercise in which the user first has to make an estimation of the carb content using the food. The Training Scale can calculate the carb content based on the weight of the food on the scale and the carb ratio and will use this information to feedback to the user whether his estimation is right, close or wrong. When the estimation has been made correctly, the information will be saved to a database so the scale learns personal user products and so the user can access food and carb data whenever away from the Training Scale.

The Training Scale consists of the scale with an outer ring that displays foods and drinks over the scale from 0 to 100 (grams of carbs per 100 grams of a product) and two places where it can weigh, plates (a big and a small part), cups (a big and a small one) and a mobile application (see fig. 43).

The ring will give insights in how products compare to each other. There are 5 modi for the ring to display different food products: breakfast, lunch, diner, snacks and drinks. By making these options visible on the scale the user is reminded that everything you eat or drink influences the blood glucose values.

The user can either put drinks or food on the scale using the big cup or big plate and is asked to make an estimation of how much of the food represents the amount of carbs. He then divides the food or drinks over the small plate or cup. The scale lets the user know when this estimation is right or wrong through a red to green light array. The level of accuracy can be defined personally. When an estimation is accurate enough the green light will start to blink, in this way guiding the user to an amount that is accurate enough for a bolus advice.

The plate is designed to be made out of one part but it does contain two separate compartments for food and carbs.

The scale is connected to a mobile application. Every time a product is used on the scale, the app will ask the user whether this product should be saved to the database. In this way the database will grow over time through performing the exercises. The app also serves as an extension of the scale because it can be used to create mixed meals. Such a mixed meal can then be used on the Training Scale as well.

The essence of the Training Scale is that it guides the user to the right amount of carbs, in this way training him visually in his carb estimation skills so he can intuitively make future carb estimations. It's goal is for the user to develop knowledge and skills by letting people think for themselves and supporting with enough feedback. To support people in their confidence of their estimation skills, the Training Scale is connected to the app, which is a growing database of information. The user can use this database in situations where he is not sure about his estimation and wants to check data.

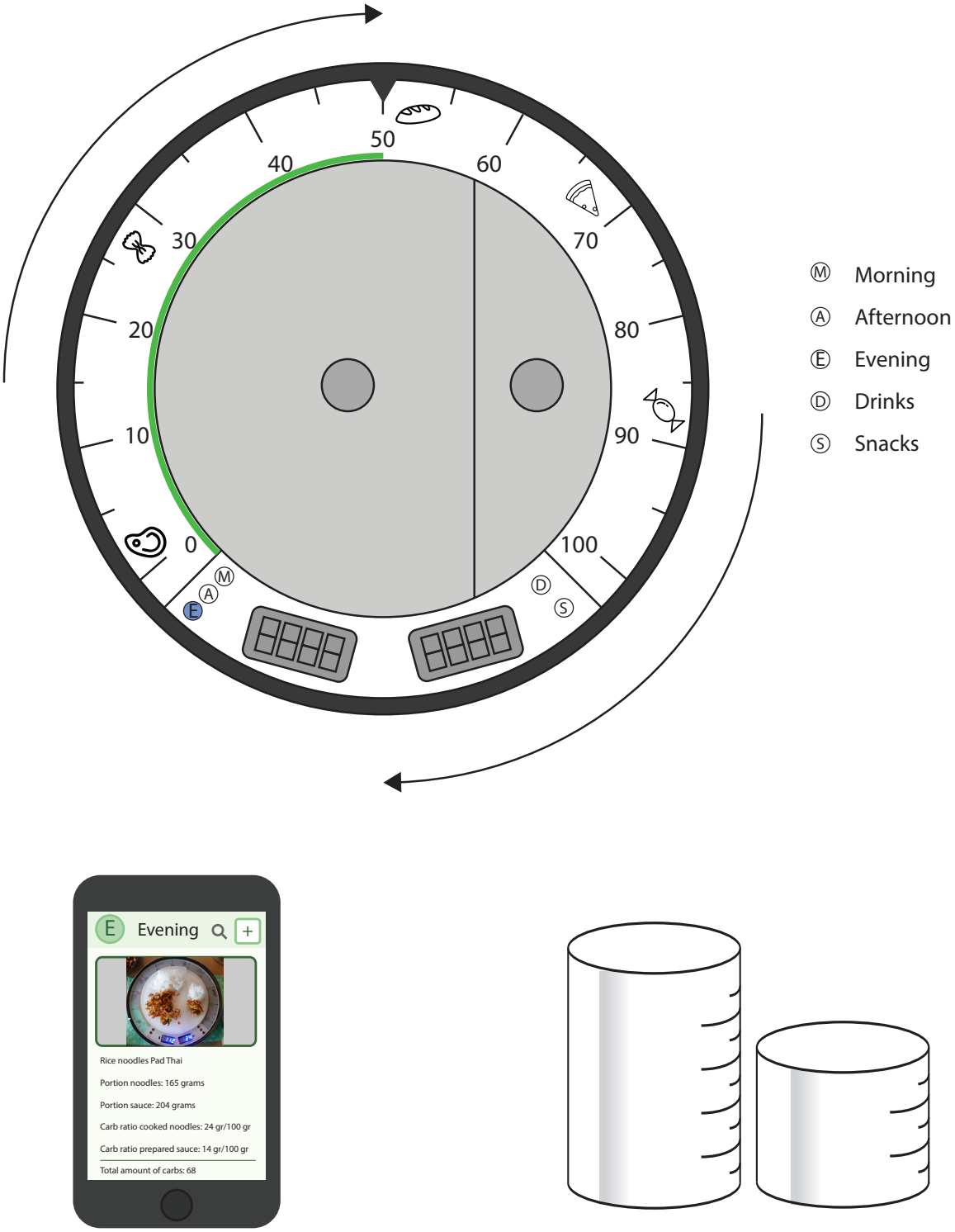
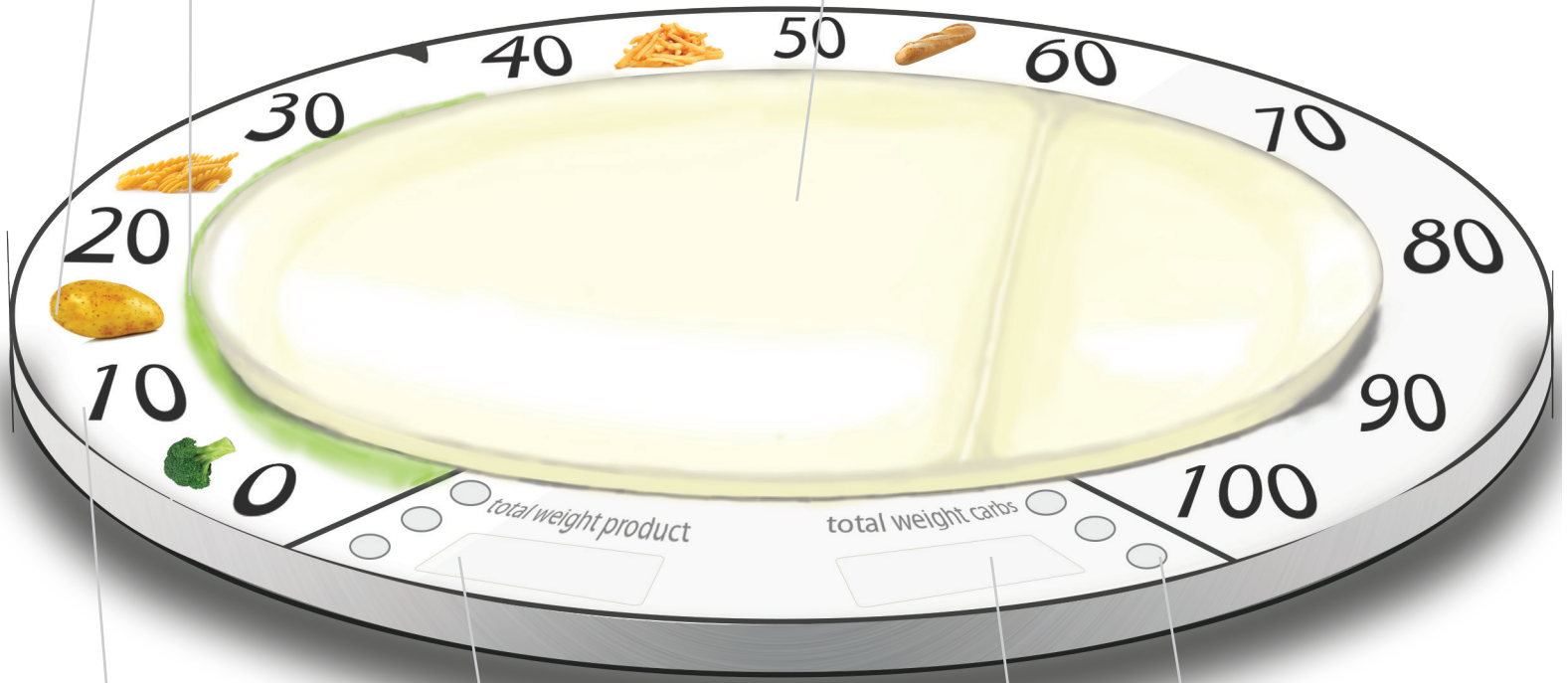


Fig. 43: Drawing of the separate parts of the final design proposal: left: the Training Scale, top: the cups for drinks, right: the mobile application showing data of performed exercises

Food and drinks appear on the ring for easy comparison of products and intuitivily finding the right carb ratio for a product:
"If the ring would display my personal products than that would be very convenient. It might bring new insights." (Appendix F, 2.1.3)

A special plate is designed for this training scale: where two parts can be weighed separately. Instead of a plate, 2 cups and 2 glasses can also be used.
"I weigh what I put on my plate, so I know exactly what I eat" (Appendix E, quote 1.3.5)

Red or green light depending on whether the estimated carb weight is right, close or wrong:
"The constant feedback could train someone more quickly and efficiently" (Appendix F, 2.1.2)



Screen returning the total weight of the product, strengthening the skill to assess how much a portion of a product weighs:
"If you train a lot on this than I do think that they eye will become better trained at determining amount but also carbs." (Appendix E, 2.4.7)

Screen returning the weight of the estimated carbs, strenthening the skill to see which part of a food represents the right amount of carbs and much this weighs:
"I didn't expect it to be this much!" (text message with photo of exercise)

Numbers representing how many grams of carbs a product contains per 100 grams of that product:
"Compared to weighing and calculating, I find reading a food label a less annoying task" (Appendix E, 2.1.5)

Six buttons for the six different modi of the ring: morning, afternoon, evening, snacks, mixed meals and drinks:
"Drinks are difficult for me, I never count them as carbs or inject insulin for it" (Appendix E, quote 2.4.1)

Fig. 44: Sketch of the Training Scale with links to research and findings of the design-research cycles

11.3 The app

The mobile application is designed with two functions in mind. First of all it serves as an extra to support to make people grow towards a level of estimating carbs independently and confidently. Secondly, it is an extension of the Training Scale making the scale more convenient.

In the beginning, people might feel insecure about estimating carbs. In that case they can look at the data in the app and use the information to make an estimation. The data that the app contains is: an index of carb ratio, portion size as eaten at home in grams, carb content of that portion and a picture of their estimation that they made at home using the Training Scale.

When using the Training Scale people have to enter the carb ratio of specific products using the outer ring. Finding a trustworthy source for these ratios has often been mentioned as an important cause for insecurities during the research cycles. Based on the interview with a dietician, the most trustworthy source is the NEVO table (See Analysis p. 21). The app contains a database of carb information of a variety of foods and drinks based on the NEVO table. However, all specific food products that have a food lable should be added to this database, making the database grow personally and more extensively. The app also provides the opportunity for the user to create mixed meals. By adding all ingredients to one meal, the app can calculate the average carb content per 100 grams of that meal. This number can then be used on the Training Scale again by entering this number using the outer ring.

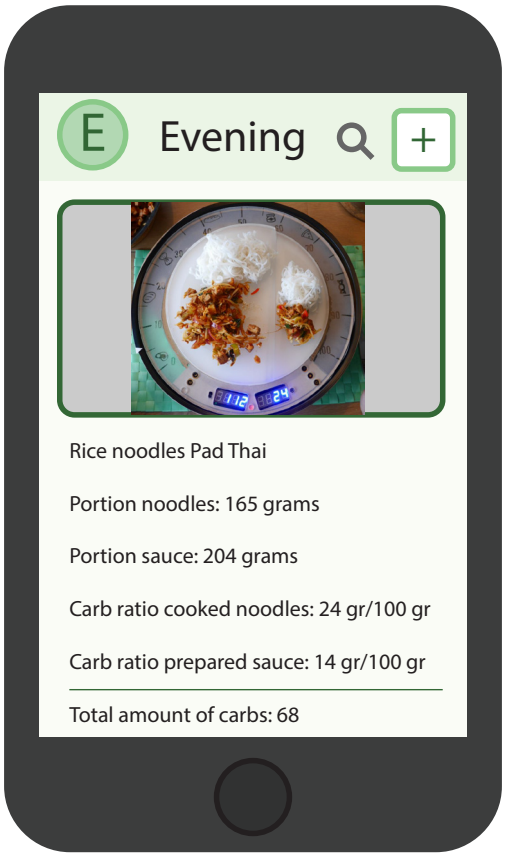


Fig. 45: Designs of the mobile application showing how the data of the exercise would be stored for later checks

Fig. 46: Design of the app showing how people could look for carb ratios in the NEVO database

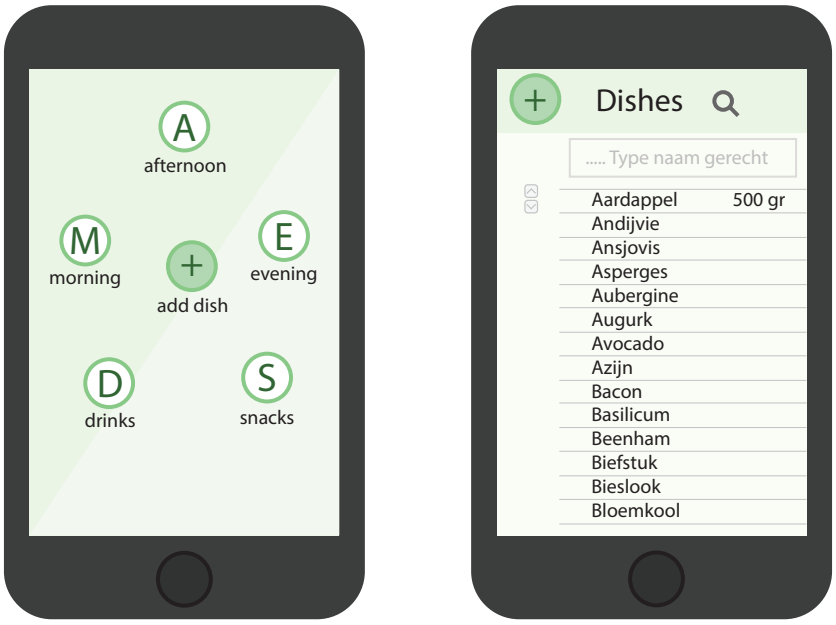


Fig. 47: Design of the app showing how people could create dishes in the app

Photo of the prototype at the diner table

11.4 Context

The Training Scale is designed as an add-on to the existing BolusCal program but it can be used in any future therapy that asks people to determine their carb content. The Training Scale is supposed to be given to people who have received a basic training about carbohydrates so it can be used at home when learning to apply carb counting in everyday life. In practice it turned out that people prefer to make the carb estimation while sitting at the table, when the food is cooked and when everyone is sitting at the table (cycle 2, p. 50). This was a moment where people could find the room and time to focus on themselves and their therapy which during cooking was not the case. A prerequisite for the final design proposal was therefore to be suitable for use at the diner table. The Training scale is designed to look like a plate so the exercise can be executed on the plate at the diner table and the user can immediately continue with eating. The exercise is designed to take up as little time as possible where the only extra actions are selecting the right food or drink and redividing them over the plate.

11.5 Who

The design assignment was set up for a broad target group: everyone who is eligible for BolusCal. Through observations it became clear that people differ a lot from each other in how they approach life, diabetes and determining carb content. Looking at the defined archetypes of the BolusCal therapy, based on this difference in approach people have different needs and wishes for an intervention to get them to change their behavior (Archetypes, p.32). Below is explained how the Training Scale applies to the tailored interventions for each archetype:

Worrier: The Training Scale builds self-efficacy through closely guiding the user to the right amount of carbs. When persisting, the user will always get to the right result, making the expected outcome very clear. The more self-efficacy is developed the more motivation the person will have to undertake action, the more likely it will be that someone will master the skill of estimating carb content.

Stubborn: These people need to see the benefit of determining carb content. By guiding them to the right amount of carbs they will feel the effect of the therapy sooner and won't be discouraged during the time of learning. The visual image of carbs and constant feedback of what they are doing makes carbs less abstract to them and will make them understand the effect of carbs on their body. This will encourage them to continue with the training and therapy.

Busy bee: People feel that they are too busy to spend much time on diabetes, their food and their carb intake. The perceived barrier of determining carb content needs to be lowered. By facilitating learning in a convenient way, they don't have to make calculations any more, in a present, physical shape will trigger action. The time spent at home on learning to estimate carbs will contribute to their skills and knowledge to estimate carbs away from home and even during busy times.

Demander: These people feel that diabetes products are behind on what is already possible with current technology and therefore do not feel taken seriously by the health system. The Training Scale saves all data prevent cumbersome repetitive actions and to be able to learn from past behavior. However, what these people actually want is that all their diabetes products are connected to each other and possibly de designed as one integrated product. There are therefore still opportunities to include this archetype even more in the use scenario of the Training Scale.

The optimist: A treatment will only succeed if a person wants to be treated (interview account manager, p.27). Therefore, people such as The Optimist, who don't really recognize what having diabetes entails will struggle with getting full benefit out of the Training Scale. If there is no perceived threat it is less likely that a person will be motivated enough to persevere in adopting a health change behavior (Glanz et al., 2008). Making people see that they are susceptible to complications and recognizing the severity of them is probably more in line with the responsibility of the health care giver rather than of a company as Roche DC.

Ideally, a variety of people can find support in the Training Scale. It is designed to adapt to how the user uses it: it can be a step-by-step guide to learn how to approach counting carbs (participant 2, cycle 2), it can be a motivator to try and learn as many different products as possible (participant 4, cycle 2), it can be a check for every once in awhile for someone who wants to refresh his knowledge (participant 1 cycle 2) and it can be a tool to create a personal trustworthy database (participant 5, cycle 2). The assignment was kicked off with tha BolusCal participants as target group. This is how the archetypes were created and how the Training Scale is now placed into context. But, really the Training Scale is so focussed on carbs that it can be translated to every therapy where people have to learn to determine

carb content. It might even be the case that it is not even limited to people with diabetes but can be suitable for everyone who is interested in learning about carbs.

11.6 Implementation

The Training Scale is designed to stimulate the user's knowledge and skills so over time the user can estimate carbs without using the scale. This means that the Training Scale is a product that by being used can possibly make itself redundant and it makes the product perfect for a loan-model. At this moment Roche DC sells the BolusCal program to hospitals, including the training materials. The Training Scale could become part of the training materials that are being sold. Hospitals can then loan the Training Scales to participants of the BolusCal program who use it for a period of 3 months. After that period the Training Scales can be returned to the hospitals and given to the next participants of BolusCal. When returning the Training Scales the participants are left with the knowledge and skills needed to estimate carbohydrates and with an extensive personal database of their products and dishes. By loaning the Training Scales to their patients, hospitals can save time on extra trainings and personal consults to people who now need extra support.

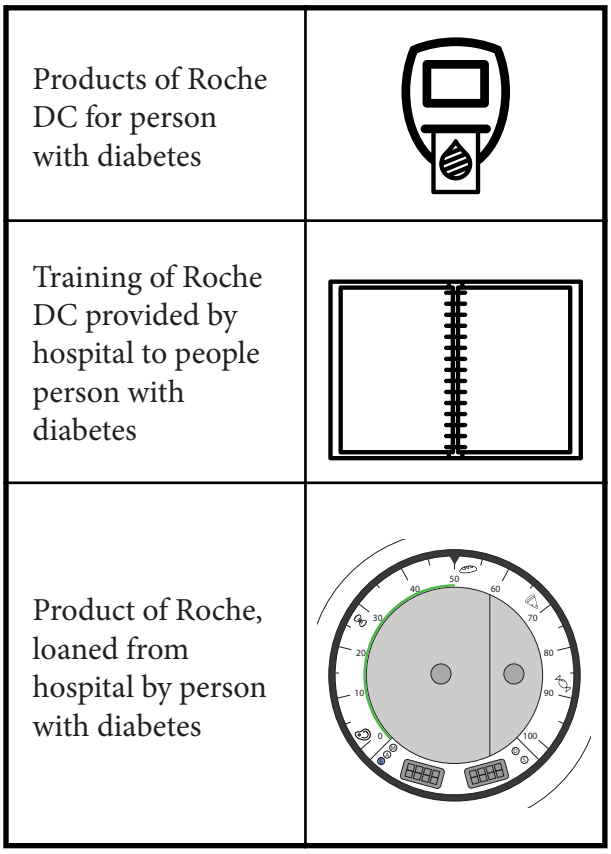


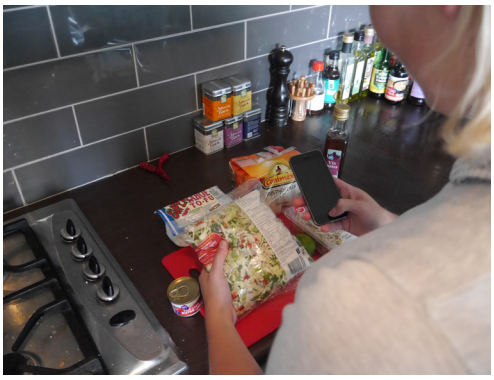
Fig. 48: Visual explaining how the Training Scale fits into the existing model and product line

11.7 Storyboard

This storyboard visualizes how the Training Scale could be user. The described scenario involved using the app the create a mixed meal and to save data to the database. The user can however choose not to use the app so for example save time.

1. The user receives the Training Scale from the hospital after having followed a carbohydrate training session.

2. When unpacking the Training Scale it can be set up using either the plates or the cups



3. Using the app a mixed meal can be created which can be used in the evening at the diner table on the Training Scale

7. Now an estimation has to be made of what part of the ingredient will represent the amount of carbs in this amount of food.

8. The color of the light indicates whether the estimation is made correctly or not. Red means wrong and green means correct.

9. By redividing the food over the plates the color will change more and more to the bright green color.

13. Again the ingredient (mixed meal in this case) can be redivided over the plates untill the light starts to blink green.

14. When all ingredients are on the plate the exercise is done.

15. The app will ask whether this meal should be saved to the database or not.

4. In the evening when the diner is cooked and everyone is sitting down at the table the training scale can be used to make a carb estimation.

5. When being turned on the lights on the scale start to go round. First, the carb ratio for the first ingredient has to be entered by turning the outer ring.

6. Next, the first ingredient can be scooped unto the big part of the plate.

10. When the green light starts to blink (it is not off in the picture) the estimation is made accurately enough

11. Now the ring can be turned to the ratio of the next ingredient. The color of the ring will return to blue and the screens grams will go back to 0.

12. This time the ratio of the mixed that was created previously has to be entered,

16. A picture can be added to the data of the meal that is saved to the database which will capture the visual image of the carb ratio.

17. By clicking the pink button in the middle, the total can be calculated of all estimations of the seperate ingredients.

18. The total amount of carbs can then be used for an accurate bolus advice.

11.8 Key aspects

This paragraph explains the key aspects of the concept and connects them to where in the research they originated from.

Weight through volume
The essence of the training is to teach people to estimate carb contentsby creating a visual representation of carbs in food, so it will be easier for people to comprehend what carbs are and how much are present in a product. If you can visually determine which part of the product represents the carbs and you have a feeling for what the total volume weighs (something that often is a given because of packages or standard serving sizes and for which people have a general feeling) it can be roughly estimated how many grams the carbs weigh. Learning to 'see' the carbs in products can be a powerful tool to cope with varying carb ratios and weight calculation. An important part of the Training Scale is that it is not limited to food products but everything from drinks, to yoghurt and soup can be estimated on it. This is important to because drinks have been known to be left out of the current therapy (cycle 2, p. 51).

Multisensory learning
Shams and Seitz (2008) have found that learning mechanisms take place optimally under multisensory conditions. Training protocols that involve stimulating multiple senses come closer to the natural world and are therefore more effective for learning. An attempt was made to apply this multisensory training protocol in the Training Scale. Of course visual stimuli are incorporated in the design by displaying the weight in numbers and by using lights and colors to communicate amount of grams and whether the estimation is close or far off. Since the connection is made between volume and weight it makes sense to also add tactile feedback as a reference to the weight of the carbs. The ring that turns around the scale is used to select the carb ratio (between 0 or 100 grams of carbs per 100 grams of food) for an ingredient or dish. Turning this ring will already provide the user with tactile feedback, this is made meaningful by making the ring turn heavier the closer you turn it to 100.

Accuracy
There is a limit in how accurate you can be in your carb calculation. Even if all tools are used to approach carb counting as accurate as possible it is still not sure that the outcome is as accurate as it seems. Multiple factors play a role here; brand differences, changing consistency over time, influence of preparation method etc. (Context analysis, interview Helga Fluit p.29). All these factors cause that a carb calculation remains an estimation. It is therefore better to teach people to estimate instead of to calculate or to count. Actually, counting carbs is a strange term: it implies that carbs can be counted one by one, whereas the intention is that people get to an amount in grams.

To prevent people from focussing too much on being accurate, on a false precision, the Training Scale does not give numbers in the decimal and the margin for being right in an estimation can be personally set. Some might be allowed to be 2 grams off, others 1 gram or even 5 grams. This margin can be personalized depending how sensitive someone reacts to carbs and insulin. This determines how accurate this person should be in his carb estimation and can be defined in the Training Scale, creating a personal goal.

Trustworthiness
During the interviews of cycle 2 it became clear that many different sources for carb ratios are used. People have lists from the hospital and use different apps, books and websites. Some apps are more complete than others whereas others are more user-friendly and insightful in storing data. However, sometimes different sources say different things causing insecurities with the users. In the end the most reliable source is the NEVO table (Nederlands Voedingscentrum) and the food labels of separate food products. This is why the database of the Training Scale is extracted from the NEVO table and every single user can add to this list based on food labels creating a personal database, not a shared one.

Back-up and flexibility
One of the things mentioned during the design session (cycle 1) is that someone had become addictively dependent of the meter. Meaning, he liked to be sure about his blood glucose values so much that he dared less to act without using the meter, making him more dependent than before BolusCal. So even though the meter made him feel more sure about his blood glucose levels, it resulted in him being even less sure when not using the meter. The fact that people can grow to be dependent on a tool that greatly helps them has been attempted to prevent during the design of the Training Scale. Ideally, people can still estimate carbs when there is no access to the Training Scale. In the end this is what the Training Scale intends to do. However it takes time to train someone in being totally independent. This is where the app starts to play an important role. The app stores all data of ingredients used in the exercise on the scale: weight of the portion, carb weight in that portion and the carb weight per 100 grams of ingredient. When an estimation has to be made away from home the user can look at the data in the app. He can then compare his current portion to the portion he usually eats at

home and based on this estimation whether the amount of carbs is less, equal or more than at home. Again, comparing two things is easier than determining the amount of carbs from scratch (cycle 2, p.50).

Support versus help

The Training Scale trains its user through an exercise in which the user has to think and try but the scale should still be a convenient tool with a low perceived barrier (Glanz et al., 2008). A very important part of the design is therefore to make a clear division in what tasks the user is being trained in and what tasks the scale should do to make things easier for the user. The user is supposed to be equiped with skills so he can intuitively estimate his carb intake. For this he needs knowledge of carb ratios of specific products and a feeling for estimating the weight for a portion of food or drinks. However, there is no need to train people in calculating or converting numbers, which is what is a cumbersome task right now (cycle 2, p. 50). Therefore, the Training Scale does this automatically. Also constantly looking up carb ratios was mentioned as a time consuming task. The Training Scale stores all data meaning that every product only has to be taught to the scale one time. Automating cognitive challenging tasks such as calculating greatly takes away a burden, relieving the user from stress they might have felt previously. The meter is greatly appreciated for making people feel sure about the amount of insulin they have to inject: "One thing less to worry about" (Cycle 1, p. 40). The Traiing Scale will hopefully make people feel secure about the amount of carbs they eat and enter in the meter.

Intuitiveness

The design of the Training Scale was important to be intuitive to its user so the learning curve in using the scale should be kept as short as possible and instead the learning curve can be focussed on developing and applying knowledge and skills. This is why a big part of the interface, the ring, is made mechanically. There is a direct coupling between the user's actions and the scale's reactions, making the use more intuitive. Also lights are incorporated to provide the user with feedforward and feedback (Wensveen et al., 2004). This direct feedback will also more intuitively teach the user to link volume to weight.

Link to theory

"People need guidance to grow towards a new behavior. At first the guidance is needed but gradually can this be replaced by self-direction as someone learns to master the steps in between towards the desired behavior" (Glanz et al., 2008, p.176).

As mentioned in chapter 6, some people currently experience the change that BolusCal asks of them as too challenging. This chapter proposes a concept in which people get offered support at home at the moment they need it most. As shown in theory, building self-efficacy plays a major role in whether people can initiate and persevere in adopting a new health behavior. People need to believe that they can make accurate estimations in order for them to master the skill. The Training Scale offers a specific learning strategy: estimating weight based on carbs visualized as a proportion in volume. Self-efficacy is built through constant feedback so the right amount of carbs can always be achieved and therefore success in estimating the right amount can always be experienced (Bandura, 1998). In the user test during cycle 4, the exercise and knowledge were perceived as valuable because the exercises had been executed using personally selected food items. It is very clear what the goal of the Training Scale is and what the user had to undertake to achieve the goal, relating to the expected outcome (Bandura, 1998). Through its physical shape the participants were triggered to think more about carbs during the days the scale was with them and learning was facilitated. Apart from learning to use the scale in the right way, the exercise is designed to take up little time. In this way giving the user the freedom to decide when and where to use the Training Scale but keeping the perceived barrier as low as possible (HBM p.26). The scale learns whatever the user teaches him, making sure not only that the user works with trustworthy information but it also becomes a realistic reflection of the users skills and knowledge.

11.9 Conclusion

The training scale is designed to guide its user as much as possible to success. When the user is persistent he will always be guided to the right amount of carbs. Through a specific learning strategy, guidance, appropriate feedback, working with personal products and a clear learning objective users of the Training Scale are supported in learning to estimate carbs. Through the addition of an app, people will also be supported when being away from the Training Scale. This will stimulate them to become independent of it and to be able to flexibly estimate carbs. Looking back at the previously defined archetypes of the BolusCal participants this concept could serve a variety of people. The people for whom self-efficacy needed to be built, for whom the benefit was not clear or for whom the current barriers are too high might be helped out especially. This concept proposes a support that underlines the importance of determining carbs for people with diabetes as well as that it creates an easier way to estimate carbs while still achieving accurate results through the power of visualization.

12. Discussion

This chapter evaluates on the final design proposal by discussing the critical points that emerged during the design research with people with diabetes. The limitations are mentioned at the overall process of this project is reflected on.

12.1 Evaluation

Final design proposal
BolusCal is a therapy designed to offer flexibility to people in an intensive insulin therapy: as long as you know what you eat you can adapt your insulin units to this. However, such a therapy can only succeed if someone is able to determine the carb intake accurately enough. This is where Training Scale enters the picture.

The Training Scale is a mixture of convenience, support and stimulation. A precondition as defined by the target group is ease, which symbolizes both simplification of carb estimating and facilitation for how the estimating should be done. However, the real interesting thing about the Training Scale is that it stimulates knowledge and skills of the user, guiding him to become an independent estimator. The user is first asked to think for himself and is given feedback based on that estimation rather than displaying the right amount of carbs in a plain number right away. The Training Scale also learns together with its user. The user enters information which the Training Scale then stores. It therefore becomes a reflection of the user's own knowledge and skills: the more it is used the more it can feedback. This tailored and natural feedback could work as a motivating factor.

People need to believe that they can make accurate estimations in order for them to master the skill. Cycle 4 showed that participants still lacked the confidence that they would succeed, however they already experienced that they always got an outcome and that the image of their food on the plate remaind for at least several days. Although, it cannot be predicted whether people would indeed grow confidence through using the Training Scale, the results do imply that guidance and the fasciliation for learning supports people in getting started with learning to determine carb intake and to persevere until an outcome has been gotten. This compares quite well to previous situations where would not know how to start or give up when things were too difficult.

The matter of the plates is a critical point and the weakest link in the current design. Right now the plate and cups are specially designed for the Training Scale causing the user to either eat or drink from a special plate or cup or he has to to scoop the food or drinks over to a normal plate or cup. The first is not desirable because it gives the user this confirmation (once again) that he is sick and the latter would mean undertaking an extra action.The use case therefore continues to be a difficult thing for the Training Scale. There were contradictions in what participants of the second cycle and of the fourth cycle indicated: people want to determine the amount of carbs when they are about to eat yet this is a moment when people want to spend little time on determining it. This was a difficult contradiction to use as a basis for a design. In the end the choice was made to design something that would support people in determining their carb intake at the table enabling the direct connection of what you see and what you estimate, in this way placing the effect of the training above the convenience of the training. There is a chance that the exercise will take up less and less time when being executed moer often which might make it less of a concern that more actions have to be taken in the beginning. Further testing will be needed to determine whether the format of the current design suits the timing and context of the particular moment and whether a growth curve indeed takes place that influence the conveniency of using the Training Scale. However, the current design does also lend itself to be used at other moments as well apart from at the diner table.

Due to the short duration of this project the long-term aspect of the Training Scale could not be included. It is therefore difficult to say something about what people would do with the Training Scale after a certain period of time. Although the intention of the Training Scale is that it is temporary: when it has been used enough, it contains the most eaten food and the exercise might lose it's challenge. Also, people responded really well to a challenge of a certain period of time, it made the duration of the effort very clear which made people better capable to be and stay motivated for that period

of time (Cycle 2, p. 50). However, some people might appreciate keeping the Training Scale, even if it is not used regularly any more, but just for a safety net. It might therefore be best to leave this open and decide on that once long-term tests can be executed.

Process
This project was kicked-off with a very clear process in mind: brief and intense field research would be followed with four design research cycles. The intention was to 'do' as much as possible as to prevent getting stuck in desktop research. It was also clear that the quality of the cycles would be determined by the involvement of the target group. Looking back, the first cycle was not entered with a clear enough focus causing this cycle to be a phase to determine the design direction rather than already making a first attempt at a design proposal. This might have been prevented by creating a clear focus earlier on in the project through extensive research. Also the scope of the assignment was set up to be very broad by Roche DC, so finding focus was already part of the assignment. Finding a focus takes time and the first cycle proved to be a very valuable step in creating a focus.

Rather than that this project consisted of four design cycles it consisted of four design research cycles. Throughout the project, research and design have alternated each other by using design activities to narrow down and using the results as implications for research and opening up possibilities. This iterative process has allowed for the concept to naturally mature instead of to result from a batch of ideas that were selected and discarded based on predefined criteria.

Looking back at all the design research cycles, many valuable insights were retrieved using various design methods. However, it might have been very interesting to involve the people with diabetes even more actively in the design process. Especially during the interviews, it became clear that diabetes, insulin and especially carbs remain abstract and complex topics to discuss. People were not always complete in their anwers and sometimes they didn't know how to feel about something. Maybe they should have been more supported in their ability to explain themselves or to imagine by for example using methods such as drawing or physically making objects.

Personal
This has been my most 'real' project I have ever done during my studies both in Eindhoven and Delft. With this I mean that I felt taken very seriously by the company I could execute this assignment for but mostly I mean that I felt that I could really do something to improve the lives of the people I have met. It taught me to listen to people's everyday experiences, deal with the complexity of everyone saying something different and finding design opportunities in people's stories.

I did struggle with the variety of people I met and with adjusting the research to that. When thinking about one participant you can already start to overestimate(or underestimate) another participant. Everyone had something different to tell which also made it difficult to make choices and find focus. However, I must admit that I discovered that I like the puzzle of trying to get everything tie together.

I feel that I have exposed an extensive amount of personal and qualitatively rich information about the every day life of people with diabetes who try to determine their carb intake. At times I was overwhelmed with the amount of information and the growing complexity with every new story.

Of course there are things that I could have done better. Some interviews might have been better prepared or the analysis of those interviews might have been done more extensively. However, my intention was to do a lot and not to get stuck in ongoing analysis. This process taught me to analyse quicky and effectively as to remain the focus and speed of the proces. Whether this was fruitful or not is hard to tell but it did lead to an interesting iterative design process.

This project taught me a lot but I hope that someday the support in whatever form or shape will indeed come available for people with diabetes, and that their life will be made just a little bit.

12.2 Recommendations

If the project were to be continued the following insights should be considered. They are derived either from evaluative tests or from side-tracks that arose during the process but that unfortunately went beyond the scope of this project.

As mentioned, during the user study with the prototype the first clues were discovered that can improve the current concept. The most important one is the user scenario. Since finding the right moment is very important for the Training Scale to be used this should definitely be tested more thoroughly. The final design proposes that a plate should be designed that enables the user to easily perform the exercise at the diner table. The user test also discovered that people probably do not like to eat from a special diabetes plate. It could therefore be researched whether the scale could be designed with special algorithms so every plate can be placed on top of it.

The Training Scale is connected to the app that enables the user to look up information of his products and to create and organize his products. Since the app was not included in the user test, the interaction between the Training Scale, the app and the user should be researched further. In light of the user scenario it would be interesting to investigate whether people want to take pictures of their plate when they are at the diner table. Special attention should be paid to the option to create mixed meals in the application. Right now the idea is that the user can create a mixed meal by listing all ingredients, either per piece or per gram. The app can then calculate what the average carb content is of that meal. However, this means that the calculated ratio is only reliable if the mixed meal is equally distributed over the plates. The accuracy and reliability of this method should be checked.

The success of the Training Scales very much depends on the frequency of it being used. If there is no regular repetition of the exercises the training might not work effectively or less efficiently. The Training Scale therefore needs to incorporate some sort of motivational trigger. An idea is to create a 10-step growth curve projected on how flexible someone is in estimating carbs. The lowest level would be eating breakfast at home: standard products in a familiar situation. A level up might mean being able to make an estimation with a new product. Even more levels up could mean a mixed meal, eating at friends, eating out and the highest level of flexibility could be to order food in a restaurant in a foreign country. This type of feedback is insightful yet playful and could add an incentive for the user to learn with the Training Scale.

Right now one specific learning strategy is incorporated in the Training Scale in one exercise: dividing the food or drink in the correct carb ratio. However, there are many more opportunities for such a scale to be expanded to multiple exercises. One participant already mentioned using such a scale to determine what she can eat on a day, as a sort of diet advisor. Another expansion could be to not only include carbs but also fats and proteins, all three are important for a healthy diet. The exercises of cycle 2 could also be revised since people reacted very positively to those exercises. For instance comparing two different products to each other might be an interesting opportunity.

Throughout the design research cycles, many interesting subjects arose that were too much of a detour for the timespan of this project but that could still prove to be interesting. One of them is including a buddy-system. During the explorative session the participants all recognized the benefit of meeting peers. It gave them the feeling that they were not alone, or that they were not doing so bad by comparison or that they could still learn from someone else. The social cognitive theory very much incorporates the social aspect of learning which works most effective when using peer models. A buddy-system could be incorporated in for example sharing estimation results between a pair, or by connecting apps in a group. Further research could point out how a buddy-system might work most beneficial for someone's learning trajectory in estimating carbs or for someone's therapy.

Personalization of products plays a very important role in how a person feels about his or her diabetes. By personalizing your products, not only functionaly but also aesthetically, you not only enter a fun factor into an otherwise all negative situation, you also create a deeper connection between the user and his/her product. This connection causes pride towards the outside world and counters feeling of shame. In other words you open up the world to respond to a disease and you open up the person towards his diabetes: it plays a role for breaking taboos and accepting that diabetes is a part of you.

References

Journals

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), Encyclopedia of human behavior (Vol. 4, pp. 71-81). New York: Academic Press. (Reprinted in H. Friedman [Ed.], Encyclopedia of mental health. San Diego: Academic Press, 1998).

Bandura, A (1998) Health promotion from the perspective of social cognitive theory. Psychology & Health, 13:4, 623-649, DOI: 10.1080/08870449808407422

Coffen, R. D. (2009). The 600-Step Program for Type 1 Diabetes Self-Management in Youth: The Magnitude of the Self-Management Task. Postgraduate Medicine USA, 121(5), 119-139. ISSN - 0032-5481, e-ISSN - 1941-9260

DAFNE Study Group. (2002). Training in flexible, intensive insulin management to enable dietary freedom in people with type 1 diabetes: dose adjustment for normal eating (DAFNE) randomised controlled trial. BMJ : British Medical Journal, 325(7367), 746.

Flanagan, J. R., & Beltzner, M. A. (2000). Independence of perceptual and sensorimotor predictions in the size–weight illusion. Nature America Inc., 3(7), 737-741. Geraadpleegd van http://neurosci.nature.com

International Diabetes Federation. (2015). IDF Atlas, Seventh Edition. Geraadpleegd van http://www.diabetesatlas.org/

Meldgaard, M., Damm-Frydenberg, C., Vesth, U., Nørgaard, K., & Schmidt, S. (2015). Use of advanced carbohydrate counting and an automated bolus calculator in clinical practice: The BolusCal training concept. International Diabetes Nursing, 12, 1-6. doi:DOI 10.1179/2057331615Z.0000000002

Rutten, G.E.H.M., De Grauw, W.J.C., Nijpels G, Houweling, S.T., Van de Laar, F.A., Bilo, H.J., Holleman, F., Burgers, J.S., Wiersma, T.j., & Janssen, P.G.H. (2013) NHG-Standaard Diabetes mellitus type 2 (derde herziening). Huisarts Wet 2013;56(10):512-25.

Shams, L., & Seitz, A. R. (2008). Benefits of multisensory learning. Elsevier Ltd., 12(1), 411-417. doi:10.1016/j.tics.2008.07.006

Sleeswijk Visser, F., Stappers, P. J., Van der Lugt, R., & Sanders, E. B.-N. (2007). Contextmapping: experiences from practice. CoDesign, 1(2), 119-149. doi: 10.1080/15710880500135987

Stappers, PJ, Sleeswijk Visser, F, & Keller, AI (2014) The role of prototypes and frameworks for structuring explorations by research through design. In: Rodgers, P & Yee, J. (Eds) The Routledge Companion to Design Research. Taylor & Francis. ISBN 978-0415706070, 163-174

Books

Arends, T., Everdingen, J. van, Heselmans, M., & Rooij, E. van. (2009). Diabetes: Een wolf in schaapskleren (2e ed.). Leiden, Nederland: Drukkerij Groen bv.

Glanz, K., Rimer, B. K., & Viswanath, K. (2008). Health behavior and health education : theory, research, and practice (4th ed.). San Fransisco, United States of America: John Wiley & Sons, Inc.

Sanders, E. B.-N., & Stappers, P. J. (2012). Convivial Toolbox: Generative Research for the Front End of Design. Amsterdam, Nederland: BIS

Conference
Wensveen, S. A. G., Djajadiningrat, J. P., & Overbeeke, C. J. (2004). Interaction Frogger: A Design Framework to Couple. Paper gepresenteerd op de DIS '04 Designing Interactive Systems, Cambridge, MA, USA. doi:10.1145/1013115.1013140

Website
Stichting Voedingscentrum Nederland. (z.j.). [Koolhydraten: Omschrijving en gezondheidseffecten]. Geraadpleegd van http://www.voedingscentrum.nl/encyclopedie/koolhydraten.aspx


50
40
30
20
10
0
M
112