TU WIEN Informatics

Analyse, Design und prototypische Implementierung einer mobilen Anwendung mit Gamification-Elementen zur Unterstützung von Menschen mit Fruktoseunverträglichkeit

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Diplom-Ingenieurin

im Rahmen des Studiums

Media and Human-Centered Computing

eingereicht von

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Analysis, Design and Prototypical Implementation of a Mobile Application Using Gamification Elements to Support Humans Suffering from Fructose Hypersensitivity

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by

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to the Faculty of Informatics

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Katharina Weindl
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ausgeführt am
Institut für Information Systems Engineering
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Forschungsgruppe Industrielle Software
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Katharina Weindl

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Wien, 26. Juni 2023

Katharina Weindl

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Kurzfassung

Nahrungsmittelunverträglichkeiten beschreiben Reaktionen oder Erkrankungen, die durch den Verzehr von Lebensmitteln verursacht werden. Der Körper kann bestimmte aufgenommene Nahrungsbestandteile nicht richtig verarbeiten, wodurch Symptome wie Blähungen und Bauchschmerzen auftreten. Fruktoseunverträglichkeit bildet eine Untergruppe der Nahrungsmittelunverträglichkeiten. Der Körper reagiert auf Fruktose, den sogenannten Fruchtzucker, der in vielen Lebensmitteln wie Obst und Gemüse enthalten ist. Als eine der Behandlungsmöglichkeiten wird eine dreistufige Therapie empfohlen, welche sich aus einer Karenzphase, einer Testphase und der Langzeiternährung zusammensetzt. Das Ziel der Therapie ist unter anderem die Ermittlung der individuellen Fruktosetoleranz und die Sicherstellung einer darauf abgestimmten ausgewogenen Ernährung. Die Verträglichkeit von Lebensmitteln ist von verschiedenen Faktoren abhängig. Dabei ist der Fruktosegehalt sowie die Kombination von Lebensmitteln ausschlaggebend. Diese Aspekte erschweren die Behandlung einer Fruktoseunverträglichkeit. Eine mögliche Abhilfe bieten Apps für Nahrungsmittelunverträglichkeiten. Eine durchgeführte Analyse von 15 State of the Art Anwendungen hat gezeigt, dass verfügbare Apps für die Unterstützung von Menschen mit Fruktoseunverträglichkeit nur eingeschränkt nutzbar sind. Die Apps helfen in einigen Lebenssituationen, jedoch stellt keine ein Gesamtpaket dar. Ausgehend davon wurde im Rahmen dieser Arbeit eine Anwendung entwickelt, um Menschen, die an einer Fruktoseunverträglichkeit leiden, umfassend zu unterstützen und die Therapie zu erleichtern. Um herauszufinden welche Anforderungen Betroffene an solch eine App stellen, wurden 14 Interviews durchgeführt. Daraus wurden 10 Anforderungen abgeleitet, die anschließend iterativ in einem Mockup umgesetzt wurden. Basierend auf dem Mockup wurde die iOS App „Let's Eat“ implementiert, welche zahlreiche Funktionen zu einer Gesamtlösung vereint. Darüber hinaus wurde ein Gamification-Konzept integriert, welches die Nutzerinnen und Nutzer auf spielerische Weise unterstützen soll, die eingeschränkte Diät langfristig umzusetzen. Abschließend wurden Benutzertests durchgeführt, um die App auf ihre Benutzerfreundlichkeit zu testen.

Keywords: *Nahrungsmittelunverträglichkeiten, Fruktoseunverträglichkeit, User-centered design, Gamification, iOS App*

Abstract

Adverse food reactions describe reactions or illnesses caused by the consumption of food. Specific nutrition components cannot be processed appropriately, causing symptoms like flatulence and abdominal pain. Fructose hypersensitivity represents an adverse food reaction where the organism reacts to fructose. This so-called fruit sugar can be found in various foods such as fruits and vegetables. One of the recommended treatments is a three-step procedure consisting of an elimination phase, a reintroduction phase and a long-term diet. The primary goal of the treatment is to determine the individual fructose tolerance and to ensure a balanced and adequate diet. The food tolerance depends on various factors. In particular, the fructose amount, as well as the combination of food products, are decisive. These aspects lead to a challenging treatment of fructose hypersensitivity. Apps for adverse food reactions can provide assistance. The analysis of 15 state-of-the-art applications has shown that existing apps trying to support people who suffer from fructose hypersensitivity are limited in function. The apps offer help in various life situations, but none of them provide an all-in-one solution. Therefore, an application that supports humans suffering from fructose hypersensitivity was developed. Ultimately, the therapy process should be facilitated. To identify the requirements for such an application, 14 interviews were conducted and the information obtained was translated into 10 requirements. Subsequently, a mockup was iteratively created. Based on the mockup, the iOS App "Let's Eat" was implemented. It is conceptualized as an all-in-one solution. A gamification concept has been integrated to support the users to stick with the restricted diet in a playful way. Finally, user testing was performed to evaluate the app regarding usability.

Keywords: *Adverse food reactions, Fructose hypersensitivity, User-centered design, Gamification, iOS app*

Contents

CHAPTER 1

Introduction

This chapter provides insights into the topic of this thesis. First, the problem statement will be presented. An introduction to adverse food reactions will be given, focusing on fructose hypersensitivity and its treatment. The thesis attempts to provide a solution to support people suffering from fructose hypersensitivity and to facilitate the therapy process. The introduction also presents the motivation of the author for writing this thesis. This is followed by the description of the expected results, in which the research questions will be proposed. Finally, an overview of the thesis structure and the methodological approach will be given.

1.1 Problem Statement

Food hypersensitivities describe reactions or illnesses caused by the consumption of food [1]. The body cannot process certain ingested food components appropriately, resulting in symptoms such as flatulence, abdominal pain, fatigue or malaise [2]. It is estimated that 1-2% of all people worldwide suffer from adverse food reactions [3].

Adverse food reactions are divided into food allergies and food intolerances. Food allergies show a defective immune response and hypersensitivity of the immune system due to individual ingested food components. Food intolerances occur, for example, due to enzyme or transporter deficiencies [1, 4]. Carbohydrate metabolism disorders represent the most common group among them. Examples are lactose, fructose, and histamine hypersensitivities, which are the most common digestive disorders, especially among the European population [5]. Fructose hypersensitivity is divided into fructose malabsorption and hereditary fructose intolerance. In the former, more fructose is added in the course of food intake than what can be absorbed in the small intestine [6]. A change in diet can provide relief in the form of alleviating the symptoms or in achieving a disappearance of the symptoms. This can be accomplished by a three-stage treatment. In the first phase, known as the elimination phase, affected individuals

only consume foods that are strictly low in fructose for a period of two to four weeks so that the symptoms decline. This is followed by the reintroduction phase, in which the individual tolerance for foods with fructose is to be determined. Dietary and symptom protocols are especially helpful in this stage. The last phase is the long-term diet, in which a nutrient-appropriate diet should be ensured. In the case of fructose hypersensitivity, this mainly concerns vitamin supply via tolerated fruits and vegetables [7].

The implementation of such a change of diet and adherence to the different treatment phases can be difficult without support. Especially the knowledge about which foods may be consumed and which may not seems to be increasingly challenging with constantly growing assortments, which frequently leads to despair among those affected. Apps for adverse food reactions such as *ALL i CAN EAT* [8], *Frag Ingrid* [9], or *HealthMe* [10] can provide support, but they have few functions and can only be used in later stages of therapy. Furthermore, no serious gaming or gamification elements are present and often basic knowledge is required for the usage. Using multiple applications for assistance is confusing and cumbersome. This problem was the starting point of this thesis. As a possible solution, an app prototype was developed to support humans suffering from fructose hypersensitivity. Ultimately, the therapy process should be facilitated.

1.2 Motivation

App solutions available for people suffering from fructose hypersensitivity offer assistance in some life situations, but they are, however, limited to a few functions. A function like food scanning can be helpful but fails for cooked food. Grocery lists within the applications often do not include specific ready-to-eat foods that are available at the supermarket. Furthermore, there is a lack of general information about hypersensitivities and concrete knowledge transfer within the apps. Above all, serious gaming and gamification elements are absent in most of the apps for adverse food reaction. There is a need for an app that combines several functions and thus offers support from diagnosis to long-term nutrition.

1.3 Expected Results

Within this thesis insights into adverse food reactions are provided. A special focus was placed on fructose hypersensitivity, its diagnosis and treatment. To find out how people suffering from fructose hypersensitivity can be supported, a requirement analysis was conducted. Based on the results, a prototypical implementation of an app was created in the course of an iterative process, which considered the individual demands and needs of the users. Gamification elements played a central role in this process. These should motivate users and support them to stick with the restricted diet. The app should help to develop a fundamental understanding of fructose hypersensitivity and to gain further insights into the topic. The usability of the prototype implementation was tested through an evaluation.

The purpose of this thesis was to answer the following research questions:

RQ01: What are the requirements for an application using gamification elements to support humans suffering from fructose hypersensitivity?

RQ02: How could a mobile application be designed and which aspects of gamification could be integrated to support the treatment?

RQ03: How is the usability of the implemented application perceived by users?

1.4 Structure

The thesis is structured into 5 chapters. In the following, an overview of the chapters is provided:

Chapter 2 focuses on the theoretical foundation of this thesis and is intended to provide a general understanding of the aspects discussed. A central part represents the explanation of adverse food reactions, carbohydrate metabolism disorder and fructose hypersensitivity. Furthermore, requirements engineering and usability will be discussed in more detail. Finally, an insight into the concept of prototyping will be given and the topics serious gaming and gamification will be discussed.

Chapter 3 covers the state-of-the-art research of this thesis. In a comprehensive analysis, different apps for people with food intolerances will be considered. Since there is a broad variety of apps available that deal with food intolerances, the focus will has been laid on applications that, on the one hand, are designed for the support of various food intolerances or diets, and, on the other hand, focus solely on fructose hypersensitivity. Various functions have been covered to gain insight into different application areas of nutrition apps. The already existing apps discussed and the implemented prototype will be compared.

Chapter 4 presents the results of this thesis. The procedure will be explained and demonstrated through several phases. Furthermore, the conduction of the qualitative interviews and the creation of the mockup will be illustrated. A detailed explanation of the implementation process follows this. Finally, the user testing and evaluation of the developed app will be described.

Chapter 5 contains the discussion of the thesis. The research questions presented in section 1.3 will be answered and an outlook on possible future work will be described.

1.5 Methodological Approach

The methodological steps to answer the proposed research questions can be divided into three main areas: research, implementation and evaluation. Figure 1.1 visualizes the methodical approach conducted in this thesis.

Research: A literature review was conducted to build a fundamental understanding of the topic. During this process, suitable interview participants were sought. The focus was put on people aged 18-60 suffering from fructose hypersensitivity. The diagnosis must have been received at least two months before participating in the interview. A total of 14 interviewees were found, containing an affected individual who also works as a nutritional expert. Subsequently, qualitative interviews have been conducted to identify the requirements for an application to support people suffering from fructose hypersensitivity. The results of the interviews performed were analyzed using qualitative content analysis according to Mayring [11]. Afterward, the information obtained was translated into requirements for the app. Based on the requirements, a prototype concept was created. This procedure answers research question RQ01.

Implementation: Based on the results of the first phase, a mockup was created. The conceptualization was an iterative process, according to the principle of "user-centered design", where the focus lies on a user-centered approach so that the design meets the needs and requirements of the target group. A total of 10 participants were involved during the different phases. After each version, feedback was gathered and the prototype was revised and improved subsequently. Based on the revised mockup, the app prototype was implemented. This approach is described by Wilde et al. [12]. The resulting application was called "Let's Eat". The completion of this step answers the research question RQ02.

Evaluation: The final step was to test the usability of the prototype. This was done in two steps. At first, the "Thinking aloud" method was conducted with four participants and feedback was gathered for further improvement. In a second step, usability benchmarking was performed. The app was tested by seven participants to evaluate the usability and usefulness of the implemented application. Additionally, feedback was collected from two participants suffering from fructose hypersensitivity. This approach answers research question RQ03.

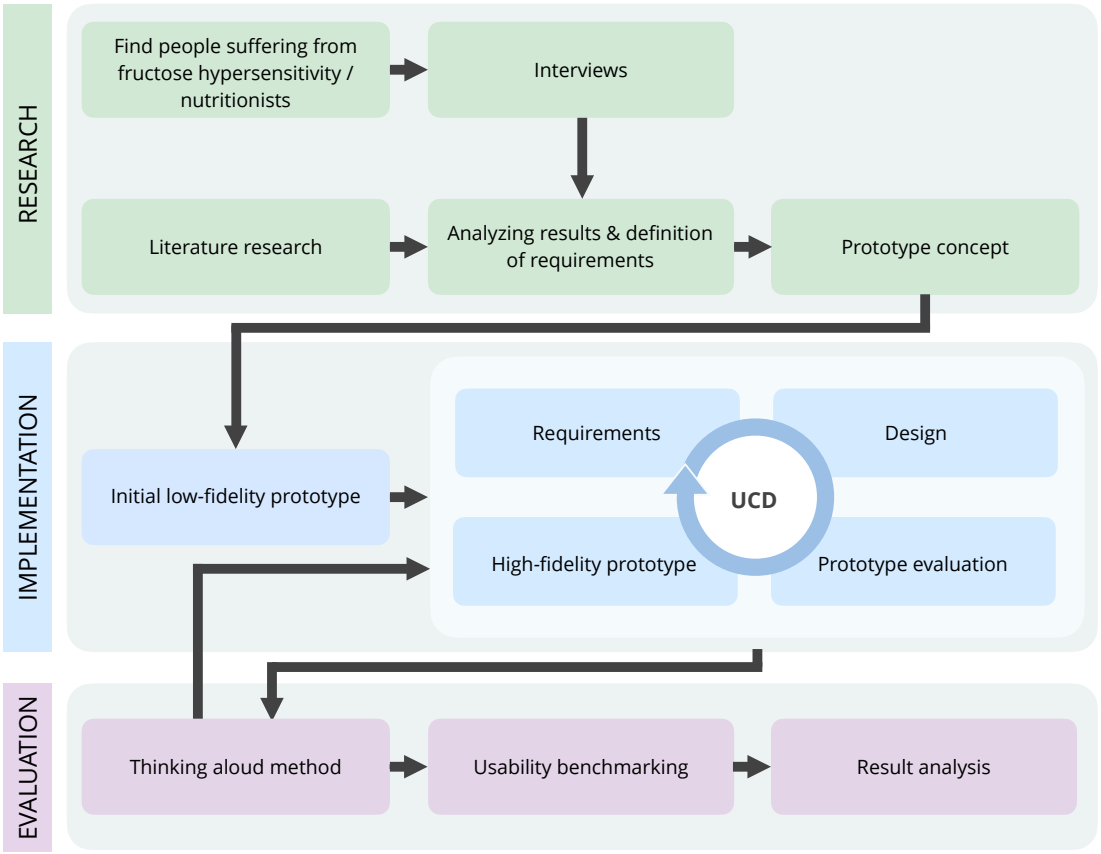


Figure 1.1: Methodology of the thesis

CHAPTER 2

Theoretical Background

Food intake represents an essential part of maintaining vital functions in the body. It ensures the absorption of necessary nutrients [13]. In society, nutrition has also become established as a cultural asset and has developed into an economic sector. Discomfort, reaction patterns, or intolerances that occur in connection with food intake therefore receive increased attention [1]. To build a fundamental understanding of the topic of the thesis, adverse food reactions will be discussed in detail and carbohydrate metabolism disorders will be explained. A particular focus will be given to fructose hypersensitivity. Subsequently, the methodical concepts used for conducting the practical part of the thesis will be explained. Requirements engineering and usability will be discussed. Lastly, the fundamentals of serious games and gamification will be described.

2.1 Adverse Food Reactions

Adverse food reactions describe reactions or illnesses caused by the consumption of food [1]. Specific nutrition components cannot be processed appropriately, causing symptoms in various body parts. The skin, the mucous membranes, the lungs, the cardiovascular system, or the gastrointestinal tract can be affected. Complaints such as itching, hoarseness, scratchy throat, asthma, swelling of the oral mucosa, nausea, diarrhea, flatulence, abdominal pain, fatigue, or general malaise are the result [2, 3]. It is estimated that 1-2% of all people worldwide suffer from intolerance to certain food products [3].

Adverse food reactions are categorized into immune mediated and non-immune mediated forms of intolerance. The former is also referred to as food allergies and the latter as food intolerances [1]. In the following, both forms of adverse food reactions will be described in more detail.

2.1.1 Food Allergies

In the case of food allergies, all components of food can be ingested, digested and absorbed by the body, but due to individual food components, so-called allergens, a misdirected immune response and hypersensitivity of the immune system occurs [1, 5]. As a result, the immune system cannot develop a tolerance to certain food components. If non-tolerated allergens are introduced through food intake, unwanted reactions in the body are triggered. The sequence of the reactions is similar to the process that occurs during the biological defense against pathogens [5]. In general, immune mediated adverse reactions to food are divided into IgE-mediated food allergies and non-IgE-mediated food allergies, with both being further subdivided. This can be seen in figure 2.1. Immunoglobulin-E (IgE) is an antibody of the immune system that is produced by the organism upon contact with certain foods in IgE-mediated food allergies [1].

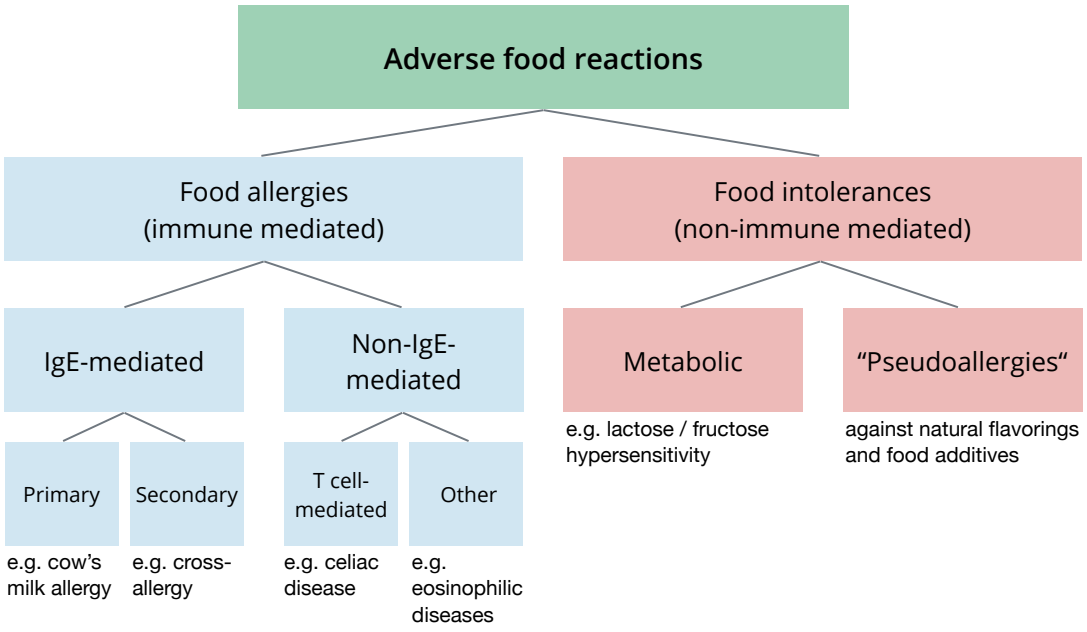


Figure 2.1: Classification of adverse food reactions (own representation based on [1, 4])

The category of immune-mediated caused adverse food reactions also include cross-sensitivities, which are also called cross-allergies [5]. These cross-sensitivities represent allergic reactions to substances with similar components to other allergens. People who are allergic to birch pollen are consecutively often allergic to apples and hazelnuts as well [14]. Examples of cross-allergies can be seen in figure 2.2.

The most common food allergens worldwide are nuts, eggs, milk, fish, shellfish, wheat and soy. Celery, mustard, sesame seeds, lupins and seafood are additionally among the most common allergens in Europe [4].

Figure 2.3 illustrates the main aspects that cause food allergies and food intolerances. These must be indicated on all packaged foods in the list of ingredients.

Relevance	Inhalation allergen	Food allergen
Common	Tree pollen	Apple, peach, plum, nectarine, kiwi, cherry, pear, almond, hazelnut, carrot, celery, potato (raw), soybean
	Common ragweed pollen	Melon (watermelon, cantaloupe melone, honeydew melon), banana, tomato, cucumber
	Mugwort pollen	Carrot, celery, caraway, parsley, coriander, anise, fennel seeds, mango, grape, lychee, sunflower seeds
	Natural latex	Banana, avocado, potato, tomato, kiwi, pineapple
Rare	Grass and cereal pollen	Flours, bran, tomato, legumes
	Ficus benjamina	Fig
	Bird allergen	Egg, poultry, offal
	Animal epidermis	Cow's milk, meat, offal
	House dust mite	Crustaceans and molluscs

Figure 2.2: Cross-allergies (own representation based on [4])

Allergens	Allergens and food products made from them
Mollusks (snails, oysters, mussels)	Crustaceans
Lupins	Cereals containing gluten
Sulfur dioxide (> 10 mg/kg or 10 mg/l SO_2)	Nuts (almond, hazelnut, walnut, cashew nut, pecan, para nut, pistachio, macadamia nut)
	Eggs
	Fish
	Peanuts
	Soy
	Milk including lactose
	Celery
	Mustard
	Sesame seeds

Figure 2.3: Mandatory declarations of food allergens (own representation based on [4])

Symptoms

The most common disorders of food allergies include symptoms in the gastrointestinal tract, including abdominal pain and diarrhea. Food allergies generally induce many independent gastrointestinal disorders. Typical allergy symptoms in other organs are skin reactions with itching and mucosal reactions in the oral cavity or respiratory tract. Among the most common symptoms in adulthood is the oral allergy syndrome, in which swelling and itching or sensitivity disorder occur in the area of the lips, oral mucosa and throat mucosa. Food allergies that manifest in the stomach or large intestine could result in an anaphylactic reaction which could be life-threatening if shock symptoms occur [4].

Diagnosis

The diagnosis of food allergies is based on a diagnosis by exclusion. In this process, diseases with similar symptoms are considered. As a next step, an anamnesis is conducted, on which further diagnostic steps depend [4].

Allergy testing, also called sensitization testing, can further be essential for the diagnosis. Specific IgE and total IgE in the blood are measured and prick tests are performed [4]. Prick tests can be used to detect immediate allergic reactions. Within the conduction of this test, allergen solutions are applied dropwise to the patient's skin and then the skin is pricked with a small lancet or needle. After 20 minutes, the reading is carried out by the medical staff conducting the prick test [15, 16]. As a further measure, laboratory determinations can be made as an additional aspect that can be considered in the testing [4].

2.1.2 Food Intolerances

Food intolerances are reactions of the human body to different foods without the involvement of the immune system. Certain components of food can only be partially or not at all absorbed by the body. These include sugar, sugar substitutes, biogenic amines or cereal ingredients. They occur due to various mechanisms such as enzyme or transporter deficiencies [3, 17]. Carbohydrate metabolism disorders, also called carbohydrate malassimilation, represent the largest and most common group among food intolerances [1]. Malassimilation is a generic term and is understood as a decreased ability to incorporate nutrients into the body [16].

Symptoms

The symptoms that may occur in the case of food intolerances are not significantly different from those of food allergies. Flatulence, abdominal pain and diarrhea, are also on the list of possible complaints of a food intolerance. However, an important difference from food allergies is that it cannot cause anaphylactic reactions. As a result, a food intolerance is not life-threatening for affected individuals, but it can significantly reduce the quality of life, just as a food allergy does [17].

Diagnosis

An anamnesis is required to identify food intolerances. During this process of gaining information about the patient, symptoms occurring after the consumption of certain foods and the degree of severity with which this happens should be documented. The frequency of symptoms is also of significant relevance. A H_2-breath-test is performed as a further step. In unclear cases, a genetic test can provide further information [17].

H_2-breath-tests are based on the measurement of hydrogen formed in the body. The patient ingests a carbohydrate solution for this purpose. H_2 exhalation is then measured at 30-minute intervals over a period of 150-180 minutes. Typically, human beings cannot produce hydrogen gas. This production only happens when bacteria comes into contact with carbohydrates, which can occur, for example, due to an enzyme deficiency in case of a food intolerance. The result is a bacterial reduction of the carbohydrates in the gastrointestinal tract. The fermentation gases produced in the process pass through the intestinal wall into the blood circuit and are then transported to the alveoli. They can then be measured by exhalation [6, 18]. The process can be seen in figure 2.4.

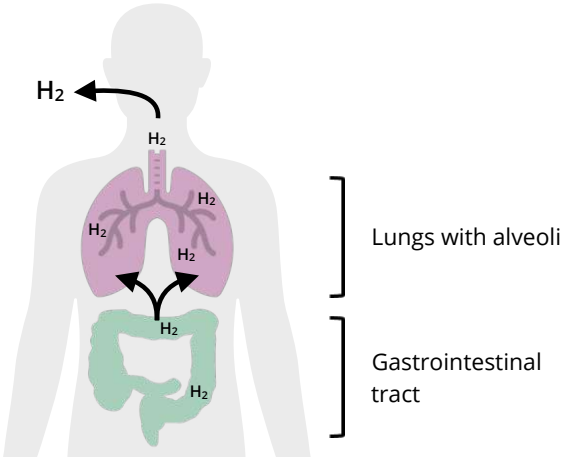


Figure 2.4: Process of the H_2-breath-test in the organism of humans with fructose malabsorption (own representation based on [5])

2.1.3 Food Allergies vs Food Intolerances

Both food allergies and food intolerances are shown by the consumption of food. Their difference results in the body's reaction to the food ingredients. In the case of food allergies, there is a misdirected immune response and hypersensitivity of the immune system. Food intolerances are caused by different mechanisms, such as enzyme or transporter deficiency.

An example is described in the following to clarify the distinction: A person may be allergic to cow's milk due to an immunologic reaction to milk protein or intolerant to milk due to an inability to process lactose in the digestive process [6].

2.2 Carbohydrate Metabolism Disorder

Many food products such as bread, potatoes, rice and cereals contain carbohydrates. They represent an essential source of energy for the human organism. The ingested carbohydrates are divided into monosaccharides in the digestive process and enter the blood circuit through the enterocytes. The body can subsequently obtain energy from the sugars. The digestion and absorption of the sugar types are ensured by specific digestive enzymes and transport proteins [7, 19].

In carbohydrate metabolism disorder, also called carbohydrate malassimilation or carbohydrate intolerance, there is impaired absorption of carbohydrates. The body is unable to process carbohydrates properly due to defective digestive enzymes or transporters. As a result, undigested carbohydrates enter the large intestine, where they are metabolized by bacteria, producing gas [1, 20]. Flatulence, abdominal pain, stomach cramps, stomach pain, diarrhea, headache, nausea or general malaise are possible symptoms [7].

The most common disorders of carbohydrate digestion include lactose intolerance and maldigestion, fructose malabsorption and sorbitol hypersensitivity. Maldigestion refers to impaired digestion due to a failure to divide food into its fundamental components. Malabsorption refers to the impaired transport of the divided nutrients. Figure 2.5 provides a overview of the subdivisions [7, 16].

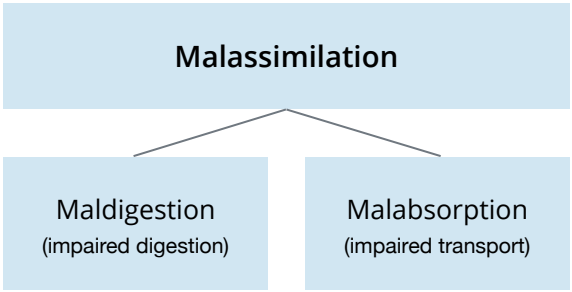


Figure 2.5: Terminology of carbohydrate malassimilation disorder

2.3 Fructose Hypersensitivity

Fructose hypersensitivity belongs to the category of carbohydrate metabolism disorders. In this case, the organism reacts to fructose, the so-called fruit sugar, which can be found in various amounts in foods such as fruits and vegetables. Fructose hypersensitivity is divided into hereditary fructose intolerance (HFI) and fructose malabsorption. The different variants of intolerance are discussed in more detail below [21].

2.3.1 Hereditary Fructose Intolerance

Hereditary fructose intolerance (HFI) is an inherent disorder of the enzyme aldolase B, whereby the supplied fructose cannot be metabolized. Aldolase B is found in the

liver, kidney and small intestinal mucosa and is responsible for dividing the fructose-1-phosphate into glyceraldehyde phosphate and dihydroxyacetone phosphate. If there is a strong impairment of the enzyme, an accumulation of fructose-1-phosphate follows since the fructose-1-phosphate can not be cleaved, which can cause a serious toxic effect. The process is illustrated in 2.6 [5, 7]. If left untreated, HFI results in hypoglycemia of the body and can later cause liver, eye and kidney damage. HFI is usually discovered in early infancy when children are fed sweetened teas in the first days of life. Even small amounts of fructose in carrot porridge trigger severe symptoms, such as elevated liver values [21, 22]. However, it is also possible that the hereditary fructose intolerance remains undetected until adulthood, as those affected often develop an aversion to fructose-containing foods on their own. Nevertheless, complete avoidance of fructose is not possible without specific dietary instructions, since fructose is present in numerous foods. Therefore, patients often suffer from affliction [5]. Generally, a genetic test can provide information on whether hereditary fructose intolerance is present [4].

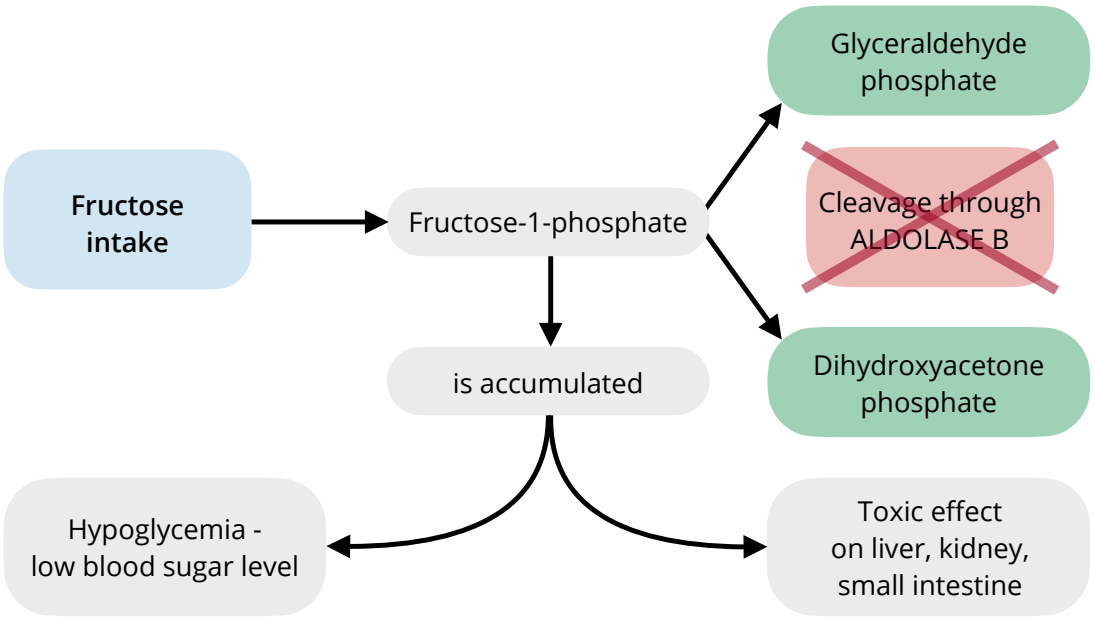


Figure 2.6: Intake of fructose in case of HFI (own representation based on [5])

Therapy

In the case of HFI, due to considerable health risks, fructose must be avoided in food intake for a lifetime. Early detection and adherence to the diet are essential to prevent a chronic course of hereditary fructose intolerance [21]. This dietary restriction must be strictly adhered especially with infants and young children aged 2-3. As the kids grow older, their tolerance to fructose-containing foods may change slightly. Therefore dietary adjustments may be possible, in which case affected individuals can reintegrate very small amounts of fructose into their dietary intake [5].

2.3.2 Fructose Malabsorption

In fructose malabsorption, the GLUT-5 transport system has a limited capacity to absorb fructose in the small intestine. As a result, the fructose contained in the food cannot be completely absorbed in the small intestine. In consequence, fructose enters the large intestine, where it is divided by bacteria [6, 23]. This process produces various intestinal gases such as methane (CH_4), carbon dioxide (CO_2) and hydrogen (H_2) [7]. These are responsible for complaints such as the feeling of fullness, flatulence and crampy stomach pain [23].

Therapy

Fructose malabsorption does not require a fructose-free diet. Although this would lead to a short-term improvement of the symptoms, it would cause attending ills in the gastrointestinal tract. Negative effects on fructose transporters result in fructose malabsorption [5]. Indeed, fructose abstinence would further decrease the functionality of the GLUT-5 transporter [24]. Therefore, in cases of fructose malabsorption, food intake should be reduced only to a tolerable level of fructose. This is usually achieved in a three-step process in which the individual's tolerance of foods containing fructose is determined. It starts with the so-called elimination phase, which is followed by a reintroduction phase with subsequent long-term diet [23]. An overview of the different therapy phases can be seen in 2.7.

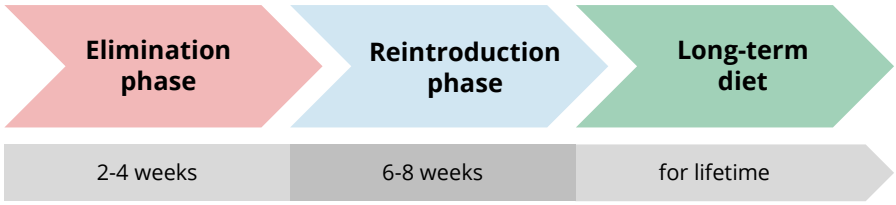


Figure 2.7: Therapy process for fructose malabsorption (own representation based on [7])

During the elimination phase, affected individuals consume only foods that contain a small amount of fructose for a period of two to four weeks. This procedure is intended to abate symptoms. Keeping a dietary and symptom protocol can be very helpful during this phase [7]. Dietary protocols and symptom protocols should be done for at least seven days. Symptom protocols are primarily used to classify symptoms and are analyzed by specialists in order to subsequently treat patients accordingly [16]. Foods that are difficult to digest are particularly problematic for people suffering from a sugar metabolism disorder, as they react very sensitively to them. Therefore, in addition to low-fructose products, non flatulent foods such as cabbage, onion plants or legumes should be eaten during the period of abstinence. Furthermore, the consumption of coarse whole-grain products should be avoided and the amount of dietary fiber should be reduced. The elimination phase is followed by the reintroduction phase, during which the individual tolerance limit for foods containing fructose is to be determined. Consumption of foods

with a higher fructose content is again allowed during this phase, but no more than one food per day should be tested. If no symptoms occur, a new food product can be tried out. However, if symptoms do occur, it is substantial to wait until the symptoms have completely declined before testing other foods. The test phase usually continues for six to eight weeks and then moves into the final phase, the long-term diet. In this final phase, the goal is to ensure a nutritionally adequate diet. In the case of fructose malabsorption, this primarily concerns the supply of vitamins via tolerated fruits and vegetables [7].

2.3.3 Diet for Fructose Hypersensitivity

Fructose represents a component of various foods such as fruits, vegetables and many other food products. The fructose level can vary widely. Onions, for example, contain a lot of fructose [13]. How well or poorly certain foods are tolerated by humans affected varies from individual to individual. Books or diet lists that can be found on the internet usually provide only limited help. Therefore a visit to a nutritionist is recommended, as an individual diet plan can be created depending on the symptoms of the affected people [24].

In general, the tolerance of different foods can be changed by selecting and combining specific foods. The amount of fructose is not determining; individual factors are also decisive [16, 23]. Moreover, everyone has a personal tolerance for certain food products. The retention time of the food in the stomach is crucial. The longer the fructose remains in the stomach, the better it is tolerated. If fructose is ingested via beverages, for example, fructose is accumulated in the stomach very quickly, resulting in symptoms developing more quickly and also to a greater extent. Furthermore, the combination of ingredients also has an impact on tolerance. With the simultaneous intake of fat, protein, fiber and glucose, fruit and other fructose-containing foods are better tolerated. Fruits, for example, that contain more glucose than fructose are therefore better tolerated by people with fructose malabsorption. These include bananas, papaya, lychee, pineapple, tangerine and grapefruit. Examples of foods that are suitable or unsuitable for fructose malabsorption can be seen in figure 2.8. High amounts of starch or sugar in food as well as the simultaneous intake of liquids shorten the retention time of food in the stomach, which leads to more discomfort in a shorter period of time [23].

2.4 Requirements Engineering

Requirements engineering represents one of the most important phases of the software development process and is conducted at an early stage [25]. It can be defined as the science and discipline of analyzing and documenting requirements [26]. Requirements engineering, therefore, aims to collect, analyze and document quality requirements for a system and the context in which the system will be used [27]. The requirements are gathered by translating the target group's imprecise, incomplete needs and wishes into complete, precise and formal specifications that must be considered during development

processes. This is done to achieve the desired functions and to meet the needs of the users [25, 28].

Unsuitable foods	Suitable foods
Fruits with a high amount of fructose, especially apples, pears, grapes, plums, blueberries, apricots and peaches as well as fruit juices, dried fruits, jam, compote, etc.	Glucose-rich fruits such as bananas, papayas, lychees, pineapples, tangerines and grapefruits
Vegetables such as artichokes, fennel, chicory, red and white cabbage, sauerkraut, onions, leeks, peppers as well as raw mushrooms	Vegetables such as potatoes, peas, spinach, asparagus, Swiss chard, cauliflower, broccoli, field lettuce, cucumbers, Chinese cabbage, pumpkin, sweet corn, celery, zucchini, fresh tomatoes and cooked mushrooms
Honey, corn syrup	
	Animal products such as meat, poultry, fish and eggs. Dairy products without added fruits
	Cereal products as well as nuts, seeds and coconut
Wine, sparkling wine, light drinks and fruit tea	Water, coffee and tea (black, green, herbal)
Sweeteners sorbitol (E 420), xylitol (E 967), isomalt (E953), mannitol (E 421), maltitol (E 965, especially in diabetic and light products), cornstarch syrup	Glucose (dextrose), malt and malt syrup, sucrose (granulated sugar), lactose, sweeteners such as acesulfame, aspartame, cyclamate, saccharin (E 954)

Figure 2.8: Food selection for fructose malabsorption (own representation based on [23])

2.4.1 Requirements

Requirements represent the description of a system before it is developed and describe what the system should be able to do. How the requirements will be implemented is not part of the requirement description [27]. Also, the eventual realization of the software is not of great relevance during this phase [29]. In general, requirements serve as an essential basis for the implementation and are necessary to know what to develop before starting with the development process. Firstly, this is done to prevent costly rework. Since technical devices are usually not very flexible and adaptations due to changing wishes and ideas of customers represent a considerable effort, complex systems must be thought through precisely before they are realized. Moreover, later adjustments can also become extremely expensive. The later errors are detected, the more expensive it will be to correct them [27, 30]. Secondly, requirements serve to communicate the required functionalities. Through a specific description of requirements, all people involved in the

development process know the functions the end product should ultimately have [30]. In general, requirements can be divided into two groups:

Functional Requirement A functional requirement specifies a function that a system or a system component must be able to perform. These so-called software requirements define the behavior of a system. These describe what the system is expected to do and how the system and the environment interact. This includes the fundamental process or transformations that system components perform on inputs to produce outputs [31].

Non-Functional Requirement Non-functional requirements focus on the "how well" aspects of the system [32]. This means it is not about what the software will perform, but how it will do it [31]. Non-functional requirements can be classified into three categories: (1) product requirements, (2) organizational requirements and (3) external requirements. The first category of requirements specifies how the product must behave in certain situations, as for example, regarding execution speed and reliability. The second one, organizational requirements, are requirements derived from organizational policies and procedures. These include process standards and implementation requirements. The third category represents requirements that result from factors outside the system and its development process. These would be, for example, legislative requirements [32]. In general, this type of requirement is difficult to test and therefore tends to be evaluated subjectively [31]. An overview of different non-functional requirements can be seen in figure 2.9.

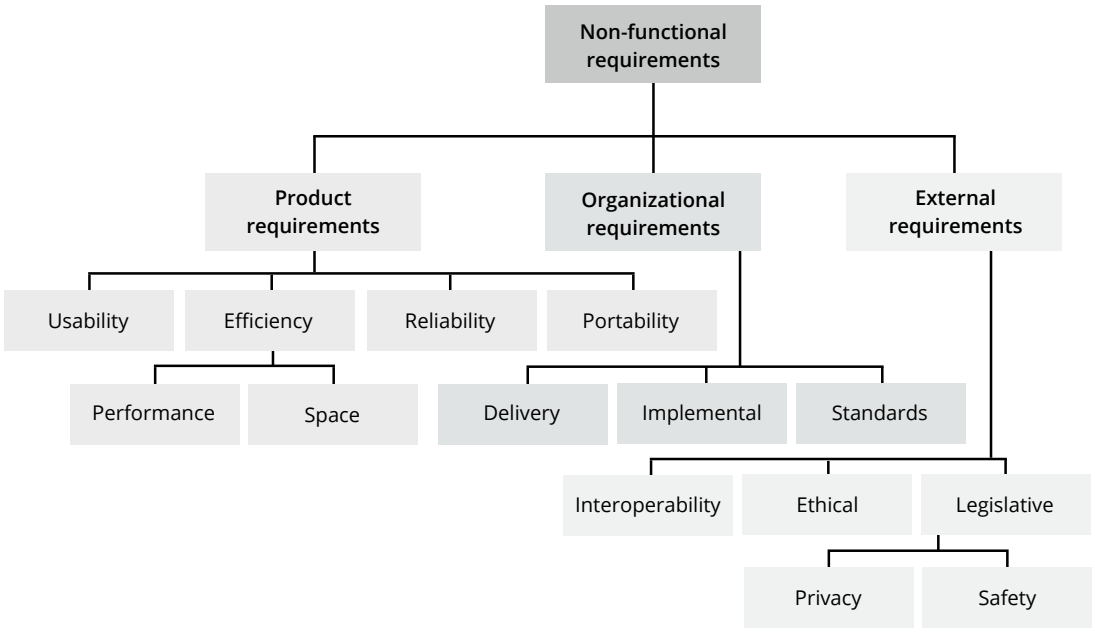


Figure 2.9: Non-functional requirements (own representation based on [32])

In general, however, requirements found in the literature are not categorized consistently in the above-mentioned two groups of requirements. Gupta and Wadhwa additionally list behavioral requirements and developmental quality attributes as own types of requirements [32]. Pandey et al. equalize functional requirements with behavioral requirements [26].

2.4.2 Stakeholder

People who can formulate requirements are called stakeholders [29]. They are either a person or organization that has a direct or indirect influence on the requirements of a system. Stakeholders take on two roles in requirements analysis: (1) being source of requirements and (2) being part of the system. *Source of requirements* means that they are involved in the course of requirements elicitation for a system. Being *part of the system* is understood as that stakeholders are part of the system environment. This means that in order to understand the requirements, a documentation of the essential characteristics concerning the stakeholders or users is required as part of the context description of the requirements specification [30]. Examples of stakeholders would be end users or buyers of the system [29].

2.4.3 Phases of Requirements Engineering

Requirements engineering is conducted as an iterative process to develop a well-thought product. It consists of the following steps: (1) elicitation, (2) analysis, (3) specification and (4) validation of requirements. This process is illustrated in figure 2.10 [25].

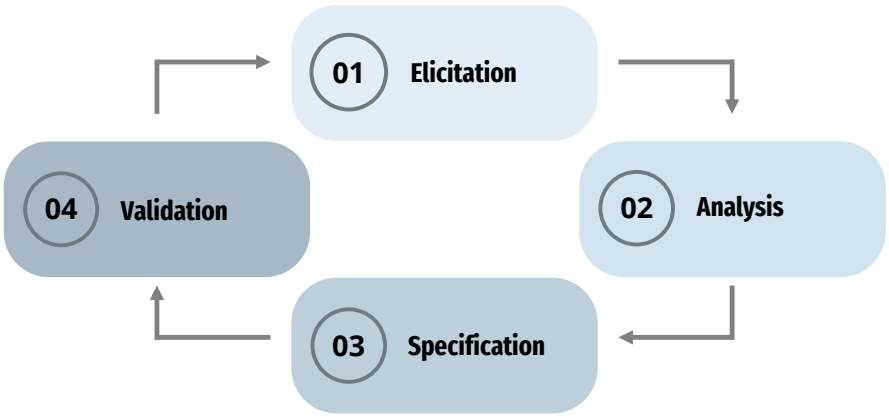


Figure 2.10: Requirements engineering phases (own representation based on [25])

Elicitation During requirements elicitation, the requirements for the intended system are determined. There are various elicitation techniques that will be discussed in more detail in section 2.4.4. During requirements elicitation, information from stakeholders is interpreted, analyzed, modeled and validated. A proper understanding of the application

domain and the needs of the stakeholders is essential. Without this knowledge, it is not possible to develop a suitable product [26].

Analysis During the requirements analysis, the requirements are checked for necessity, consistency, completeness and feasibility. When checking for consistencies, it is significant to see whether there are any contradictions in requirements. In terms of feasibility, if the requirements can be realized within the available budget and schedule should be controlled. In this phase, problems are to be solved and compromises achieved. Requirements that affect key functions are prioritized [26, 27].

Specification This phase is about communicating requirements between stakeholders and developers. The requirements document serves as an evaluation basis for subsequent products and processes as well as for change control. Therefore, a requirements document should be unambiguous, complete, correct, understandable, consistent, concise and feasible [27].

Validation Requirements validation is about ensuring that the correct requirements have been stated and that these requirements are correct. The former step is called validation and the latter is called verification [26].

Paetsch et al. describe, in addition to the phases mentioned above, a fifth step in the requirements engineering process, the so-called management phase: the task of this phase is to capture, store, disseminate and manage information [27].

2.4.4 Requirement Elicitation

The quality of the system depends on the quality of the defined requirements, which is why the choice of the right techniques for requirement elicitation is essential [28]. Requirements elicitation techniques are ways and procedures to obtain requirements, forming the foundation for the entire software development [33]. There are different methods and techniques to gather requirements. Reham et al. divide the different techniques into five categories: (1) traditional techniques, (2) cognitive techniques, (3) group elicitation techniques, (4) prototyping and (5) contextual techniques [25]. A fairly equivalent categorization can also be found in a paper written by Yousuf et al. where they classify the techniques in four categories with *prototyping* not regarded as a category of its own, but assigned to group elicitation techniques [33].

Traditional techniques involve generic data collection techniques. Examples include questionnaires, surveys, interviews, task analysis, domain analysis and introspection. *Cognitive techniques* have knowledge/requirements gathering techniques used to collect and prioritize requirements, such as protocol analysis. *Group elicitation techniques*, involving teams or groups of software engineers, are used to gain a better understanding of requirements. This includes group work or brainstorming. *Prototyping* serves likewise for the collection of requirements. It can be used for gathering precise feedback. Examples

of *contextual techniques* would be conversation analysis and observation/social analysis [25]. In this technique, requirements are gathered in the context of the user. This means that the requirements are collected in the end user's workplace [28].

In general, the appropriate choice of the requirement elicitation technique for a project depends on the project itself. Different techniques are more suitable than others for specific projects. The technique chosen for the development of one project is not necessarily suitable for another project. The appropriate choice depends on various factors such as available resources, project type or personal preferences [33]. The available time also plays an essential role [25].

In the following, techniques are described that have direct relevance to this thesis since they have been considered methods for the practical part.

Document Analysis This requirement elicitation technique involves gathering and analyzing information from existing literature to gain a more detailed insight into a specific topic. However, human interaction may sometimes be necessary to supplement or confirm information. This technique is mainly used when improving or replacing an existing system and when stakeholders and users are not available. It is classified as a traditional technique [33].

Brainstorming Brainstorming is an informal discussion between participants where everyone can freely express their ideas. The focus lies on a specific topic on which the participants can contribute creative ideas. The goal is to develop a variety of new ideas in a short period. The more ideas are generated during the brainstorming process, the higher the quality of the resulting requirements. The technique belongs to the group elicitation techniques. It is generally easy to implement and requires very few resources [25, 33].

Interviews The technique of conducting interviews is used to elicit requirements for a system and understand its goals. It is a conversational or verbal method that makes it particularly easy and effective to share ideas and express needs. In a face-to-face conversation with one or two people, questions are asked and answers are documented. These lead to requirements for the system. Interviews can be conducted in different ways. In general, there are three types of interviews: (1) structured, (2) semi-structured and (3) unstructured. In *structured interviews* predefined questions are asked to the interviewees and, like semi-structured interviews, are used to collect quantitative data. *Semi-structured interviews* include both predefined and unplanned questions. The last type of interview, called *unstructured interviews*, is used to collect qualitative data and obtain an informal interview with no predefined questions. This type can be seen as an open-ended discussion with the stakeholders to understand the user's expectations. Interviews represent an traditional technique [25, 33].

Questionnaires Questionnaires are a convenient way to collect requirements and also a traditional technique. They are used when face-to-face interviews or online meetings

with the people to be interviewed are not possible. Questionnaires are mainly conducted to survey larger population groups and facilitate the collection of information in the case of different geographical areas and time zones. The questionnaire must be clear, well-defined and precisely formulated in order to be able to determine user requirements, aims and constraints through this technique [25, 33].

User Scenarios User scenarios describe real situations in which a user interacts with the system. This includes conducted tasks and the user's participation in these tasks. The technique belongs to the group elicitation techniques and can be used as soon as the initial requirements are defined. User scenarios include complete descriptions of all processes of a system from the user's point of view. This means that the initial state, flow of events, concurrent activities, end state and others are specified in scenarios [33]. Scenarios can be used to validate requirements and create test cases [25].

2.5 Usability

In general, usability represents a sub-area of the broad question of user *system acceptability*. This is about whether the system is good enough to meet the needs and requirements of users and other potential stakeholders. System acceptance is again derived from *social* and *practical acceptability*, which in turn can be categorized into their sub-areas. Among others, these include *cost, support, reliability, compatibility with existing systems* as well as the *usefulness* of a system. The category of usefulness deals with the question of whether the desired goal can be achieved through the use of a system. Usefulness is further divided into *utility* and *usability*. The utility of a system deals with the question of whether the system provides the functions that users need. Usability is concerned with how well the functions of a system can be used by the users. The definition will be discussed in more detail below [34]. The categorization can be seen in figure 2.11.

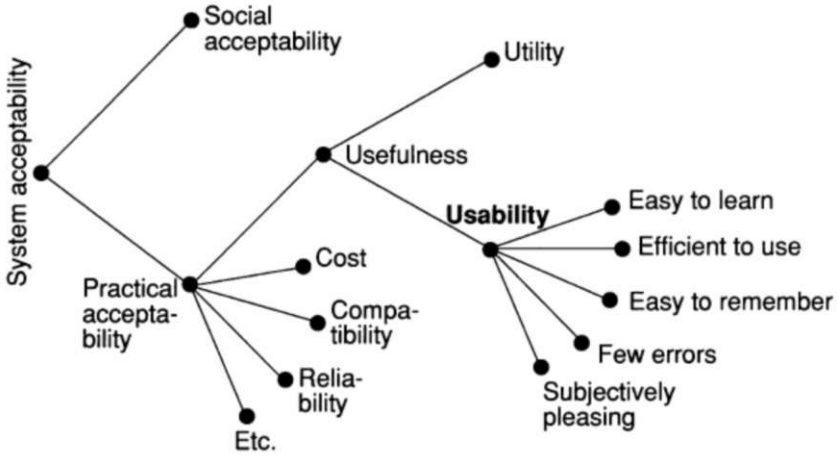


Figure 2.11: System acceptability [34]

Usability generally refers to all areas of a system that a human can interact with. It describes how well or poorly a user can use a function. This also includes installation and maintenance procedures. Nielsen defines usability as a composition of five attributes: (1) learnability, (2) efficiency, (3) memorability, (4) errors and (5) satisfaction [34].

However, the definition of the International Organization for Standardization (ISO) 9241-11 standard has prevailed, which defines usability as follows: "*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" [35]. *Effectiveness* stands for the accuracy and completeness with which users can reach certain goals. *Efficiency* describes the resources used by users to achieve their goals in terms of accuracy and completeness. *Satisfaction* expresses freedom from discomfort and a positive attitude when working with the product. *Context of use* describes the characteristics of the people using the product, the tasks and the organizational and physical environment [35].

Usability is usually measured by having several representative stakeholders execute a given set of tasks using the system that should be tested. Another possibility would be to perform those measurements on real users in the field. This would not require the users to perform additional tasks since the measured tasks would be performed anyway by the users [34].

2.5.1 User-Centered Design

User-centered design (UCD) is applied to both hardware and software development. It is a design philosophy and approach for digital and non-digital products. UCD is generally a broad term describing the concept of system end-users having an influence on how the product will ultimately look. It is therefore about placing users at the center of the entire development process [36]. There are different approaches to how exactly users are involved in the development process and regardless of how different they are, the only important thing is that the users are involved in the process under all circumstances. In some forms, the involvement is done through the planning and design process by asking users about their needs or integrating them during requirements gathering and usability testing. In other concepts of user-centered design, users have a major influence on the design by providing input throughout the design process [37]. In any case, when a new product or application is developed, the focus is on the needs of the people who will later deal with the application. Therefore, the development team must focus on real-world scenarios in which future users will use the product [36]. The purpose of a system is not only to be used and have a nice design, but to serve the users and directly support them during their work [38]. Product designers, therefore, have the mission of making tasks easier for the user through their products and ensuring the product can be used as intended with a minimum of learning effort [37]. Gould and Lewis describe that any system which is to be used by humans should be easy to learn, useful and pleasant to use. The term *useful* means in this context that the system contains features that people need to carry out their work [39].

One of the most widely adopted principles of user-centered design also originates from Gould and Lewis. They formulate the following three core principles that form the basis for implementing user-centered designs in design projects [39]:

Early Focus on Users and Tasks As a first step, designers need to understand who the users of their products are and then involve them in the design process. Focusing on the user means that they have to be observed during the design process to identify their current tasks in their daily lives and at work. The aim is to understand the full context of these tasks. Therefore, the observation should include conceptual models, actions, demographics and knowledge of the users [36, 39]. This principle is not about how to develop a new technology and what needs can be met, but about finding out what the users want to accomplish and how technology can support them to achieve this [36].

Empirical Measurement In the development process, users should use simulations and prototypes to perform real tasks of their daily lives. During this process, their reaction and performance should be observed, recorded and analyzed [39].

Iterative Design The design process of a product must be iterative. This means that if a problem occurs during user testing, the designer must redesign elements to resolve the issue. This results in so-called circles of design that are performed as often as necessary. The steps involved are design, test, measure and redesign [39].

These three design principles from Gould and Lewis have been translated into four primary activities in the ISO 9241-210 standard [40]:

1. Understand and specify the context of use
2. Specify the user requirements
3. Produce design solutions to meet user requirements
4. Evaluate the designs against requirements

These four activities are intended to help meet users' needs by applying a UCD approach throughout the life cycle of a system. They are performed in an iterative process, which can be seen in figure 2.12 [36]. A detailed explanation is given in the following:

Understand and Specify the Context of Use: This involves understanding the context and environment in which a user will use a product and the tasks she or he wants to accomplish with it [35].

Specify the User Requirements: During this activity various criteria for the usability of the product, design guidelines and constraints should be defined. The needs of the users should be understood to meet their requirements. [35, 40].

Produce Design Solutions to Meet User Requirements: Knowledge of human-computer interaction should be integrated into the design. This includes the visual design, interaction design and usability [35].

Evaluate the Designs Against Requirements: In this step the usability of the designs is evaluated based on user tasks [35].

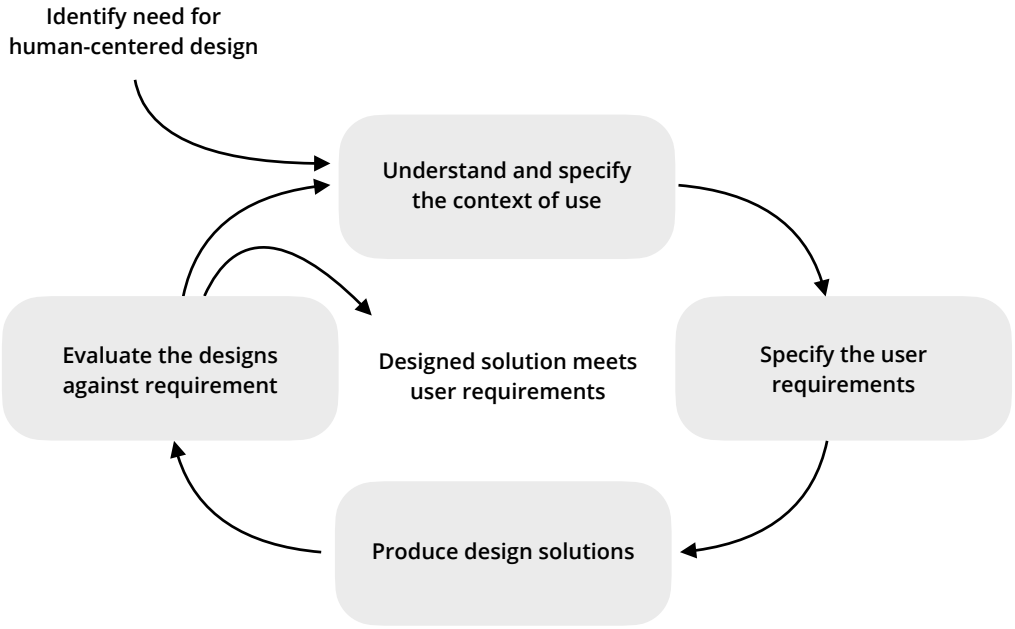


Figure 2.12: Activities of user-centered design (own representation based on [35, 40])

The user-centered design method provides a framework and guidance in the form of principles for the design process. However, implementing the frameworks can lead to inherent difficulties in establishing them in practice. Reasons for this are that not everyone involved in the project is familiar with the principles or there are ambiguities in interpreting the principles. Therefore, usability engineering emerged to address this problem [36].

2.5.2 Usability Engineering

Usability engineering represents an approach to achieve usability in the system development process. User demands for usability are trying to be understood and systematically fulfilled. The aim is to develop systems adapted to the needs of the end user [41]. Usability engineering aims to integrate central concepts and insights from human-computer interaction (HCI) into software design processes. HCI deals with the design, evaluation and implementation of interactive computing systems designed for humans [36]. Structured methods and theories of usability engineering include different areas of psychology,

sociology, physiology and human factors. A distinct understanding of the motivation, characteristics and working environments of users through these processes should be provided. Through an iterative design and evaluation process, customer opinions on functionality and product design are requested throughout the development cycle. This is done to ensure that the end product meets the customers' needs [41].

2.5.3 System Usability Scale

The system usability scale (SUS) represents one method that can be used to assess the usability of a product or a service. The goal is to provide a measure of peoples' subjective perception of the system's usability over the shortest possible period [42]. SUS consists of 10 statements participants have to answer. Each statement has a certain number of points that will be calculated and summed up in the end providing a score in the range from 0 (negative) to 100 (positive). Since the score does not clarify the absolute usability associated with it, Bangor et al. have revised the system and created a comparison of different scales in relation to the average SUS score. This can be seen in 2.13. A score between 90-100 represents an exceptional product, while below 70 points means that the rated product has usability problems [43].

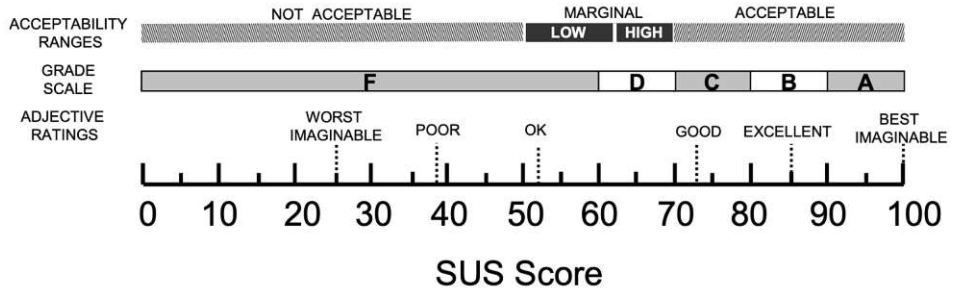


Figure 2.13: SUS result interpretation [43]

SUS represents a *Likert scale* [42], which was developed in 1932 to measure "attitude" in a scientifically accepted and validated way. The attitude in this context refers to a preferential way of behaving or reacting in a specific circumstance [44]. The Likert scale used for the SUS was created from a pool of 50 potential questions that covered possible user reactions to various aspects of the system's usability. Brooke [42] has selected two software systems, a linguistic tool for end users and a tool for system programmers, the former being a very easy-to-use system and the latter challenging even highly skilled users. Twenty people from Brook's office systems engineering group with diverse backgrounds (for example, secretary, systems programmer) had to rate both systems on a 5-point scale using the 50 questionnaire items. This scale ranged from "strongly agree" to "strongly disagree". The 10 statements that led to the broadest differences between the easy-to-use and the challenging software system were then selected from the pool [42, 45]. They are listed in the following figure 2.14.

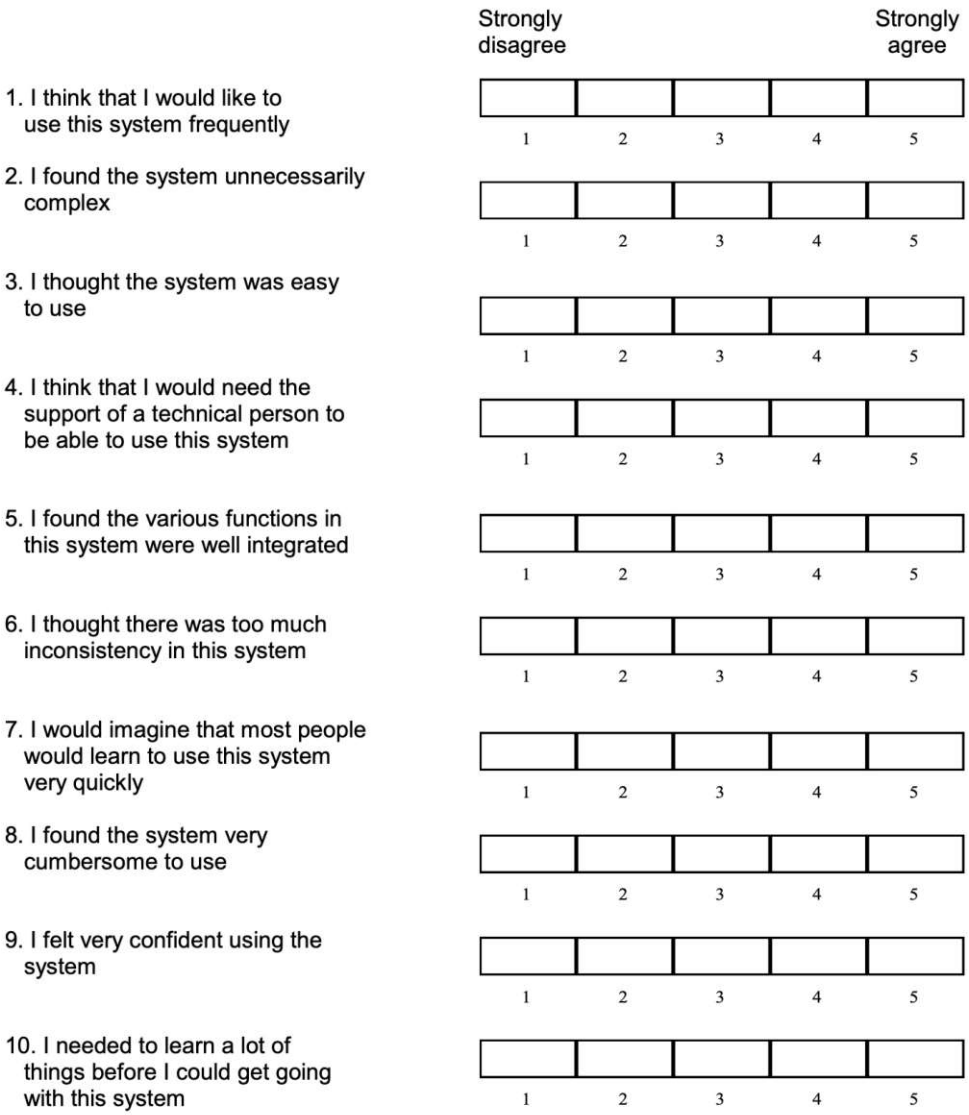


Figure 2.14: Statements of the SUS [42]

The SUS should be used after the test person has had an opportunity to operate with the system and before any discussion takes place. If the participant feels that she or he is not able to answer a specific statement, the center point of the scale should be selected. The calculation of the SUS score follows a specific principle: first, the SUS score for each statement is calculated. For odd items (1, 3, 5, 7, 9), 1 gets subtracted from the selected response of the users. For even numbered statements (2, 4, 6, 8, 10) the test person's responses gets subtracted from 5. This ensures that all score contributions range from 0 to 4, with 4 being the best possible rating. Finally, these calculated values get summed up and multiplied by 2.5 so that the result is within the range of 0 to 100 [42, 45].

2.6 Use Cases and Use Case Diagrams

Use cases represent textual descriptions of the interaction between external entities and the system. External entities, also called actors, include users, other computer systems or external events. An external event would be reaching a specific date or time [46]. Cockburn et al. define uses cases as follows [47]:

> "*A use case is a collection of possible sequences of interactions between the system under discussion and its external actors related to a particular goal.*"

On the one hand, use cases serve to document system requirements. On the other hand, they can be used for the communication between different participants of a software project. An example of the latter would be the use of use cases to communicate between the system developers, future users and owners [48]. Furthermore, use cases allow the system to be understood without describing the implementation in more detail [46].

Use case diagrams represent graphical visualizations of use cases. They display the relationship between actors and use cases as well as the connection between use cases. In general, both use cases and use case diagrams should be easy to interpret by users. This means they are written in a "user language" [46].

2.7 Prototyping

A prototype is an artifact with which design ideas for a product are tested, explored and communicated [49]. The artifact can be seen as an early version of a future-developed product. The prototype contains essential functions that can be tested by users and serve as a guide for further production. It represents a learning vehicle that provides more concrete ideas for the target system [50]. Prototyping is a convenient way of involving users in the design process since prototypes are better understood by the users than specification documents of system components.

Prototyping represents an iterative process in which the system is improved step-by-step based on user feedback. This technique is especially valuable when stakeholders do not know their requirements for the system or when early stakeholder responses are needed. The aim is to develop a system that meets the requirements of the stakeholders [25, 33]. Budde et al. define prototyping as a four-step process: (1) functional selection, (2) construction, (3) evaluation and (4) further use. In the *functional selection* step, a decision is made as to which functions are to be implemented in the prototype. With the help of the prototype, these can then be tested by users. *Construction* refers to the effort required to develop the prototype. The choice of appropriate techniques and tools is essential to keep the effort as low as possible. The *evaluation* is a significant step in prototyping, as the feedback gained during evaluation is relevant for the future development process. Future users from the target groups should be included in the evaluation phase. The step *further use* of the prototyping process depends on two factors:

firstly, on the experience that could be gained through the prototype and secondly, on the available production environment. It can later serve as a learning vehicle and be thrown away after usage or it can be reused partly or entirely as a component for the new prototype or the target system [50].

Compared to the final product, prototypes either have fewer functions or a limited scope of functions, this means that functions only seem as if they would function. The former is called vertical prototyping and the latter horizontal prototyping [34]. The different types are explained in more detail below:

Vertical Prototyping In the case of vertical prototyping, the number of functions of the prototype is reduced. This means that the prototype contains only a few functions from the set of functions that the finished product will have at the end of the development process. Through that only a part of a system can be examined when using vertical prototyping, but all parts included in the prototype are fully implemented. This method allows testing the product under real conditions and with real user tasks [34].

Horizontal Prototyping Horizontal prototyping means that the scope of functionality of the prototype is reduced. When looking at the prototype all functions seem to be present and functional, but the depth of functionality has been eliminated. The functions only seem to work, while in reality, they do not. A horizontal prototype can therefore be seen as a simulation of the user interface, through which it is possible to test the entire user interface, but under less realistic conditions than in vertical prototyping [34].

Classifying prototypes in vertical/horizontal prototyping represents only one possibility of categorizing prototyping. Prototypes can also be distinguished by their fidelity. A distinction is made between low-fidelity prototypes and high-fidelity prototypes. Fidelity represents the degree to which prototypes differ from the end product and how easily aspects of the design can be manipulated to simulate the functionality of the later system [51].

Low-Fidelity Prototyping This type of prototype serves as a simple illustration of the product and is implemented primarily in early development phases. An example of a low-fidelity prototype would be sketches. Low-fidelity prototypes are often created using simple materials such as paper, pens and sticky notes. They differ from the end product in interaction style, visual appearance and/or level of detail. The focus is on interaction design and information architecture rather than design and visual components [30, 51].

High-Fidelity Prototyping High-fidelity prototypes represent a software prototype of the interactive system that is to be developed. It already has a clear resemblance to the finished product [30]. This type of prototype represents interactions realistically and can better convey design possibilities [51].

2.8 Serious Gaming and Gamification

The term "serious games" was first defined by Abt [52]. He describes serious games as games that contain a well-thought-out educational purpose and are not primarily intended for entertainment. Michael and Chen also define serious games as games that do not have entertainment, enjoyment or fun as their primary purpose. In general, this does not mean that serious games are not entertaining, enjoyable or fun. Instead, the primary purpose of this game category lies on a different focus [53]. Laamarti et al. define the term "serious" in serious games in the sense that serious games aim to convey a message or input to the player. This can be knowledge, skills or generally some content [54].

Games are effective teaching and learning devices for students of all ages and can be used in a lot of situations [52]. They are present in many areas of knowledge, for example, military, health, manufacturing, education and medicine [55]. The fact that games can convey the concepts and facts of various subjects very efficiently makes them extremely useful. Games produce dynamic representations of problems existing in the real-world that are studied. Players take on real roles, are confronted with problems, formulate strategies, make decisions and receive quick feedback on the consequences of their actions. The people playing the game can experience this without the cost of real-world consequences or mistakes [52]. Players should be supported to learn something and, if possible, have fun doing it [53]. Serious games are not limited to any genre, can be implemented with any game technology and can be developed for any platform [56].

Various descriptions and definitions of games can be found in literature. Wattanasoontorn et al. defines a game as a physical or mental competition with a goal or objective. It is played according to a framework or rules that define what a player can and cannot do during the game. Games can be described by five different components, which are illustrated in figure 2.15.

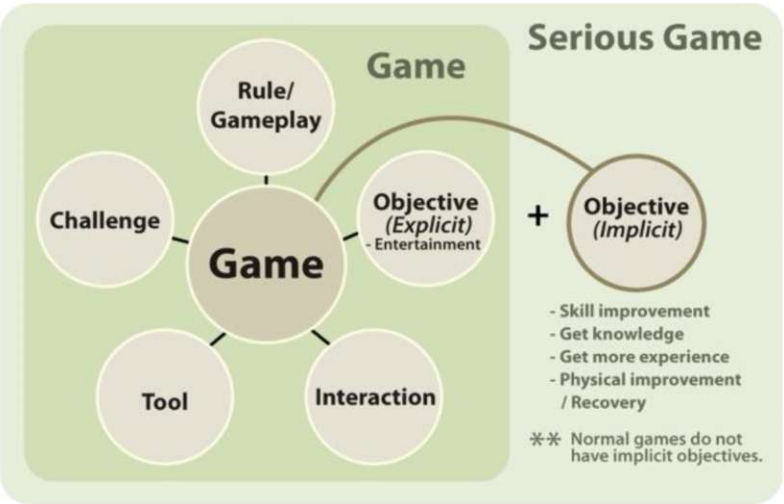


Figure 2.15: Functions of serious games [55]

The first component is the *rule* or *gameplay* that connects the game and the player. The second component is the *challenge*. This includes rewards for good actions or overcoming obstacles and barriers. Challenges are integrated to create different levels of difficulty in the game and motivate players. The third component is the *tools* associated with the interaction component. These obtain devices or accessories that are connected to the game to provide input data. An example would be the Wii Balance Board, which is able to trace the user's center of balance. The collected data from the device can be used in the game environment. The fourth component represents the *interaction* between the player and the game. Interaction in this context refers to any action taken by the player. There are different ways an action can be performed. Examples would be visual, auditory, physical (tapping, mouse, touchpad, button press) actions or via dialogue. The fifth and final component remains the *objective* to be achieved or completed through effort or action. There are two types of objectives: explicit and implicit. Games with explicit objectives are only about entertainment. Implicit games involve the improvement of skills and abilities, the acquisition of knowledge or the acquisition of experience. Based on this distinction, serious games can be differentiated from other games since they contain implicit objectives. It is also possible, however, for serious games to contain explicit objectives additionally. The difference to entertainment games will be further substantiated in the following section 2.8.1 [55].

2.8.1 Serious Games vs Entertainment Games

Djaouti et al. defines two dimensions in the context of games: a *serious* and a *game* dimension. The serious dimension consists of a non-entertaining purpose and the game dimension refers to a video game structure. Serious games represent any piece of software combining both dimensions [57]. Serious games aim to achieve some change in, for example, the player's knowledge, attitude, physical ability, cognitive ability, health or mental well-being [58]. The fun factor is not primarily relevant. In contrast, entertainment games contain only the game dimension and aim to provide their players with the greatest possible experience, joy and entertainment. Entertainment games could also affect a player in a way like serious games do, but, however, those effects are mainly side effects and not their purpose [57, 59].

2.8.2 Classification of Serious Games

There are various classifications of serious games proposed in the literature for different areas. Ratan and Ritterfeld created a classification of serious games for learning based on a dataset of over 600 serious games. The dataset contained English language games, most of which originated in the United States, with a small number developed in Asia and Europe. Serious games were categorized into four dimensions: (1) primary educational content, (2) primary learning principle, (3) target age group and (4) platform. Each of these categories is further subdivided [60].

- **Primary Educational Content:** This category includes content that makes

the game serious and not just entertaining. The category is further divided into several areas: academic education, social change, occupation, health, military and marketing. Games can also contain several types of educational content [60].

- **Primary Learning Principle:** Serious games have the advantage offering the possibility of exploration, experimentation and problem-solving. Therefore, different learning principles can be found in serious games, which can be divided into the following categories: practicing skills, knowledge gain through exploration, cognitive problem solving or social problem solving [60].
- **Target Age Group:** Serious games are divided into target groups based on age. There are four age categories: (1) preschool and below (2) elementary school, (3) middle school and high school and (4) college, adult and senior. In the last category, it should be added that while certain games are intended only for seniors, for example, most games above the high school level are no longer geared to specific age groups. Therefore, no further subdivision is made here [60].
- **Platform:** The platform chosen for a serious game can also have an impact. Platforms differ in their control interface, such as keyboard and mouse, screen sizes and potential mobility [60].

In contrast to the classification of Ratan and Ritterfeld stands the taxonomy of Laamarti et al., whose classification is based on characteristics that are important for the design and success of a serious game. The taxonomy consists of five main categories: (1) application area, (2) activity, (3) modality, (4) interaction style and (5) environment. The categories are described in more detail below and are shown in figure 2.16 [54].

- **Application Area:** The application area characteristic refers to the different application domains for serious games. The most important areas include education, advertising, health care, well-being, cultural heritage and interpersonal communication [54].
- **Activity:** This second characteristic describes the type of activity performed by the player and which is required by the game. It is divided into physical exertion, physiological or mental activities. Physical activities are used in games for personal well-being or in games for obesity. Physiological activities are used for rehabilitation games or to detect certain health conditions. Mental activities are applied in games with an educational context, for training or interpersonal communication [54].
- **Modality:** The characteristic modality describes the channel through which the information is transmitted from the application to the player. The feature therefore categorizes how a player experiences the game. The modality is distinguished in visual, auditory and haptic. However, there are also attempts to use the sense of smell in games. The right choice of modalities can improve the user experience and increase the success of the application [54].

- **Interaction Style:** The interaction style feature defines the player's interaction with the game. This interaction can be either through traditional interfaces such as keyboard, mouse, or Joystick or it can be done through more advanced interfaces such as brain interface, eye gaze, movement tracking and tangible interfaces. The choice of the interface in the development process of the game can be key to the success of the game [54].

- **Environment:** The environment of a serious game can be a combination of several criteria. The first category of game environments is whether the serious game is developed for a *2D* or *3D* environment or *a combination of the two*. Next is whether the game is a *virtual* or *mixed-reality environment*. Virtual reality means that the world is completely synthetic and that it is either a computer-generated immersive environment representing the real world or pure imagination. Mixed reality consists of augmented reality and augmented virtuality merging the real and digital world. The remaining categories are *location awareness*, which is relevant for games that want to use the users' current location, *mobility*, *online* and *social presence*. The category *online* deals with the possibility to play the game over a computer network like the internet and *social presence* refers to single or multiplayer games [54].

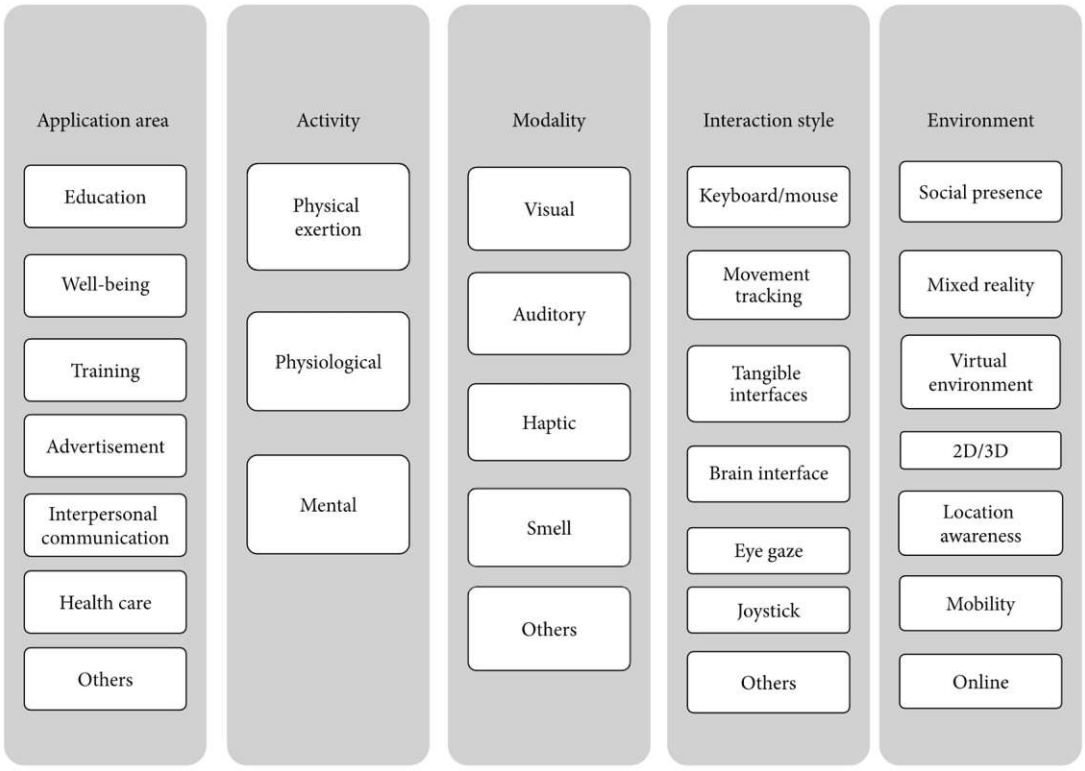


Figure 2.16: Taxonomy of serious games [54]

Serious Games in Health

Health is a central issue that affects people in every phase of life and represents a fundamental need with high priority. Serious games offer many possibilities for application in the health sector. An example would be the usage as an additional means to increase interest in education, training and user performance evaluation. Medical staff can receive education and training through these sorts of games to avoid medical errors. Serious games also offer possibilities in rehabilitation processes, where they can be used to support patients in performing repetitive tasks [55].

As with serious games per se, there are also different classifications of serious games in the health sector. Rego et al. have created a taxonomy for serious games in the rehabilitation area with nine categories. These combine some of the categories already mentioned above. The main criteria for serious games are categorized as: (1) application area, (2) interaction technology, (3) game interface, (4) number of players, (5) game genre, (6) adaptability, (7) performance feedback, (8) progress monitoring and (9) game portability [56].

McCallum has created a taxonomy for categorizing different types of games used in healthcare. This taxonomy distinguishes between five health activities focusing on different types of change: (1) preventive, (2) therapeutic, (3) assessment, (4) education and (5) informatics. The last three categories can be summarized as informal types of change [58]. The exact classification can be seen in more detail in figure 2.17.

Area of health activity	Personal	Professional practice	Research and academia	Public health
Preventative	"Exergaming" Stress	Patient Communication	Data Collection	Public health Messages
Therapeutic	"Rehabitainment" Disease management	Pain distraction Cyberpsychology Disease management	Virtual humans	First responders
Assessment	Self-ranking	Measurement	Inducement	Interface and visualization
Educational	First Aid Medical information	Skills and training	Recruitment	Management simulations
Informatics	Personal health records	Electronic medical records	Visualization	Epidemiology

Figure 2.17: Taxonomy of games for health [58]

A further classification possibility for serious games for health would be according to the affected area of health. A distinction is made between games for physical, cognitive and mental health [58].

In developing games for this specific sector, the determination of the target audience is of great importance for designing the experience and measuring efficiency. Games from the

academic environment typically focus on a limited age group and set a specific health goal. The primary purpose of this step is to be able to measure the health goal later on. The target audience for a developed game can be defined as *narrow* or *broad*. Narrow audiences would be groups focusing on a specific age, gender, race, location, or other characteristics. The main advantage of this restriction is that the game experience can be tailored to the cognitive, emotional, or physical characteristics of the players. The broader the target group becomes, the more difficult it is to design the experience and measure the effect on the users. In addition to dividing the target group, the desired outcome of the game is also split into *specific* or *general*. A specific health outcome, for example, can be found in rehabilitation games. In those games, success can be easily measured. However, the positive impact of such games on the general population is not as high as in games with general outcomes such as exercise games (exergames). Those games have the potential to change the health of the population to a greater extent [58].

In general, it must be said that serious games for health are not designed to replace doctors and therapists. Instead, it is about supporting the patients and improving the treatment [53].

2.8.3 Gamification

Gamification represents the use of game design elements in non-gaming contexts [61]. Motivational affordances of game experiences are used in gamification to influence psychological outcomes and further behavioral outcomes. Effective gamification is composed of a combination of game design, behavioral economics, motivational psychology and user experience. When implemented effectively, gamification can achieve an increase in user motivation [62].

According to Deterding et al., gamification involves elements from the area of gamefulness, gameful interaction and gameful design [61]. The term gamefulness refers to the lived experience. The experience of gamefulness evoked by objects, tools and contexts is referred to as gameful interaction and gameful design refers to the practice of designing a gameful experience [63].

2.8.4 Game and Game Elements

In this section, a definition of the term games will be given before the most important game elements will be discussed in more detail.

Games are created by designers or teams of developers and consumed by players [64]. Various definitions of games can be found in the literature. Abt defines games as "*an **activity** among two or more independent **decision-makers** seeking to achieve their objectives in some **limiting** context*" [52]. Seaborn et al. describe several definitions of games, including the definition of games as "*representations of some reality, be predicated on the interaction between the system and the user and provide conflict but also safety through simulation*" [63]. It is further described that all games contain the following seven features: (1) rules, (2) variable, (3) quantifiable outcomes, (4) value-laden outcomes,

(5) player effort, (6) player investment and (7) negotiable consequences in terms of real-life impact [63]. For Hunicke et al. the main distinct components consist of: rules, system and fun [64].

The most commonly used framework for game design is called MDA, standing for mechanics, dynamics and aesthetics. The MDA framework represents an analysis of game elements. It should help to describe the interaction of the different game elements using systems thinking and to be able to apply it outside of games [65, 66]:

- **Mechanics:** Describe the individual game components in terms of data representation and algorithms [64]. This includes, for example, points and badges [66].
- **Dynamics:** Describe the interaction of the player with the game mechanics. The game dynamics are about the player's reaction to the mechanics, both individually and together with other players. With time pressure and opponent play, it is possible to create challenges in the game [65, 66].
- **Aesthetics:** Describe the desired emotional reactions of the player caused by the interaction with the game system [64]. This includes emotions that arise, for example, from the feeling of being challenged [66]. The game aesthetics can be seen as the result of the game mechanics and dynamics [65].

The mechanics of a gamified system consist of a series of tools. Garett et al. have conducted a study to examine the most popular gamification elements used in healthcare contexts. Gamification elements can be seen as the basic building blocks for games. The result of the study conducted can be seen in table 2.1. In general, many lists of important and recurring game elements can be found in the literature [67, 68]. A more concrete explanation of an excerpt of game elements will be given in the following.

Points

Points can be found in a variety of games and gamified applications. Typically, players receive them as reward for successfully completing certain activities within the game environment. They serve as a visualization of progress and also for feedback. The players' behavior in the game is measured and it is possible to give continuous and immediate feedback to the players by giving them points. Points are divided into several types [67]. Zichermann et al. describe five different scoring systems [65]:

- **Experience Points:** This type of points represents one of the most important point systems. Experience points (XP) have the purpose of observing, evaluating and guiding the player. For each action a player performs in the game, she/he receives XP points and they normally can not decrease. In some games, it is however possible that they expire, for example, monthly or annually. This aims to create goal loops. An important aspect of XP is that there is no limit. As long as the game is played, XP points can be earned.

Ranking	Game mechanic	Definition
1	Points	Does the study reward participants with points or virtual currency for completing certain tasks
2	Social interaction	Could users interact with each other (collaboration, completion/tournament, comments)
3	Leaderboard	Does the study use leaderboards to display how each participant is doing (a table listing leaders in a competition)
3	Progress status	Does the study allow participants to check their progress
4	Levels	Does the study allow participants to level up
5	Immediate feedback	Does the study provide immediate feedback after completing certain tasks
6	Narrative	Does the study have a storyline or a theme
6	Badges/medals	Does the study reward participants with badges or medals
6	Reward system	Does the study allow participants to exchange points/virtual currency with online or offline perks, such as new accessories for avatars

Table 2.1: Popular gamification elements (own representation based on [68])

- **Redeemable Points:** Redeemable points (RP) differ from XP in the way that they can fluctuate. RP can be used to buy in-game goods in exchange for things, for example. They are consequently earned and redeemed through actions of the user. RP form a virtual economy and are often referred to as coins, bucks or cash.
- **Skill Points:** This third type of a points system is bonus points, which are assigned to specific activities. If a player successfully completes an activity, such as a task or a sub-goal, she/he receives additional points.
- **Karma Points:** Karma points rarely appear in classic games. They can be given away to other players. Keeping them does not bring any advantage to users, only sharing them can have a beneficial effect. The purpose of karma points is to create a behavioral path for altruism and user reward. Users can thank each other for well-done tasks using these kinds of points.
- **Reputation Points:** Reputation points represent the last type of points systems. They serve as a substitute for trust between two or more parties.

Leaderboard

The purpose of a leaderboard is to provide a comparison between players. Leaderboards measure the success of players regarding certain success criteria and rank them accordingly.

The performance of one player is compared to the performance of another player [67]. Zichermann et al. distinguish between two types of leaderboards that are often used within games [65]:

- **No-Disincentive Leaderboards:** This type of leaderboards represent primarily a tool for creating social incentives instead of disincentive. The actual rank on the leaderboard usually does not play an essential role as long as the player's rank is not within the top 10 or 20. At the launch of the game the player is initially ranked in the middle of the leaderboard. The most important aspect is to be on the list and not the actual position on the leaderboard. The leaderboard also shows friend players who are, for example, further down the list and try to catch up with the player. This creates an incentive for the user to keep her/his place on the leaderboard or to reach a better one, because it is clearly visible how many points are missing to the next better rank on the leaderboard [65].
- **Infinite Leaderboard:** Infinite leaderboards are based on the assumption that a player's score will eventually be beaten by another player. Since users can not stay on the leaderboard forever, infinite leaderboards provide a solution to this problem with integrated multiple layers. Doodle Jump, for example, has three different views for the leaderboard: local, friends and global. This can be seen in 2.18 [65, 69].

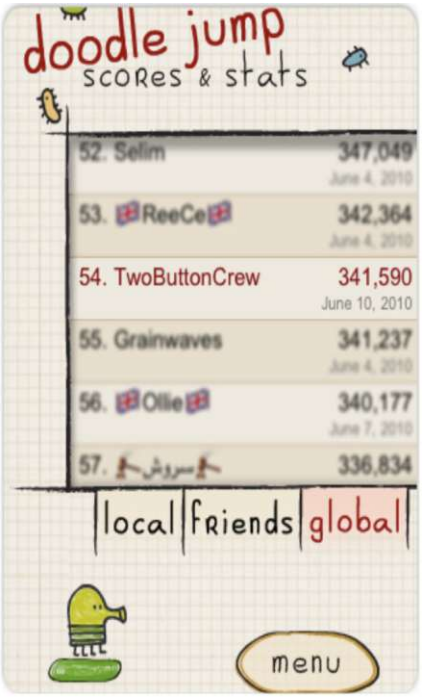


Figure 2.18: Leaderboard of the game Doodle Jump [65]

Progress Status

The progress status is used, for example, as a percentage progress indicator for a player. In other areas, progress status indicators are also used to show whether all required credentials are present such as the needed personal information for the user account [65].

Levels

Levels serve players as both an indicator of their progress and as a marker of where they are in the game. Furthermore, levels take on different roles. In some games, as the number of the level increases, the difficulty or leading element of the game changes and in other games, the depth and complexity of the game increases with each level. In general, the increase in difficulty per level is not linear but increases in a curvilinear form [65].

Figure 2.19: Example of a game level map [70]

Badges

Badges are a visual representation of achievements in the game. They can be earned and collected in the game environment. Badges can be achieved by reaching a particular score or performing certain activities. They serve as a confirmation of players' achievements, a symbolization of merits and a visualization of the accomplishments of levels or goals. Moreover, these game elements act as status symbols and a visualization of game progress. Furthermore, badges are also a way of providing feedback to the player and serve as motivation to complete certain routes or challenges to earn certain badges [65, 67].

Figure 2.20: Examples of game badges [71]

CHAPTER 3

State of the Art

This chapter describes currently existing apps that support people suffering from food intake problems. There is a broad variety of apps available that deal with the topic of food intolerances. In the following, the focus will be on applications that, on the one hand, are designed for the support of various food intolerances or diets and on the other hand, focus only on fructose hypersensitivity. For this purpose, apps were searched in the App Store [72], Google Play Store [73] and in the scientific literature. The search terms used in the stores were “Fruktose”, “Fructose”, “Unverträglichkeit” and “Einkaufsassistent Unverträglichkeit”. The goal was to cover a wide range of different functions to gain insight into the various application areas of nutrition apps. The chapter will be concluded with a summary and comparison of the apps under analysis.

3.1 Apps for Various Food Intolerances

In this section, different apps will be analyzed that focus on multiple food intolerances and different diets. Firstly, two apps are presented that are intended to support individuals in diagnosing if specific food components are not tolerated or if they are suffering from a particular hypersensitivity. The subsequent applications are considered to help people suffering from a hypersensitivity in different therapy phases through a variety of functions.

3.1.1 BesserEsser

BesserEsser is an app that can be used to identify if a food hypersensitivity is present. Humans confronted with frequent gastrointestinal symptoms, such as abdominal pain, bloating or nausea can use the app to determine if the symptoms are caused by food intake. With expert knowledge and artificial intelligence, lactose, gluten, fructose and sorbitol sensitivity can be diagnosed. This evaluation is based on the data entered by the users themselves in the app. More precisely, the meals eaten and symptoms that occurred

can be recorded in the *BesserEsser* app. Meals can be categorized into breakfast, lunch and dinner. A calendar provides the user an overview of the documented meals and symptoms of the last days or weeks with the usage of different colors. For example, a day with an underlying green dot means a meal has been entered and a red dot means that the user had some symptoms on that day. If the meals and symptoms are recorded regularly, a result is provided after a short time, declaring whether an intolerance is present. Figure 3.1 illustrates the calendar dashboard with some entered meals and the available options when clicking on the "+"-button [74].

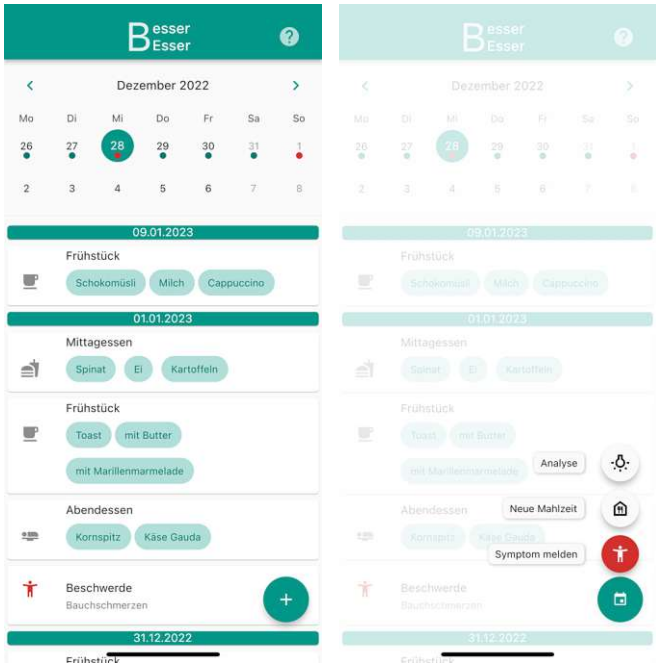


Figure 3.1: App *BesserEsser* [74]

3.1.2 CarboCeption

CarboCeption is an app that can be used to perform a test for the detection of a carbohydrate metabolism disorder. The time that would normally be spent in the laboratory or at a doctor's office to detect a carbohydrate malassimilation should be saved through the use of the app. The test consists of eight steps performed in sequence. A test type, for example, fructose, must be selected, questions have to be answered and test substances or foods must be chosen within the test process. During the test, whether symptoms are present or not must be stated at frequent intervals. The total duration of the test is three hours. Subsequently, the user will be informed about the results and further recommendations. Besides this function, the app includes a guide that contains information about the test substances, sensitivities and general information about food intake. The app is illustrated in figure 3.2 [75].

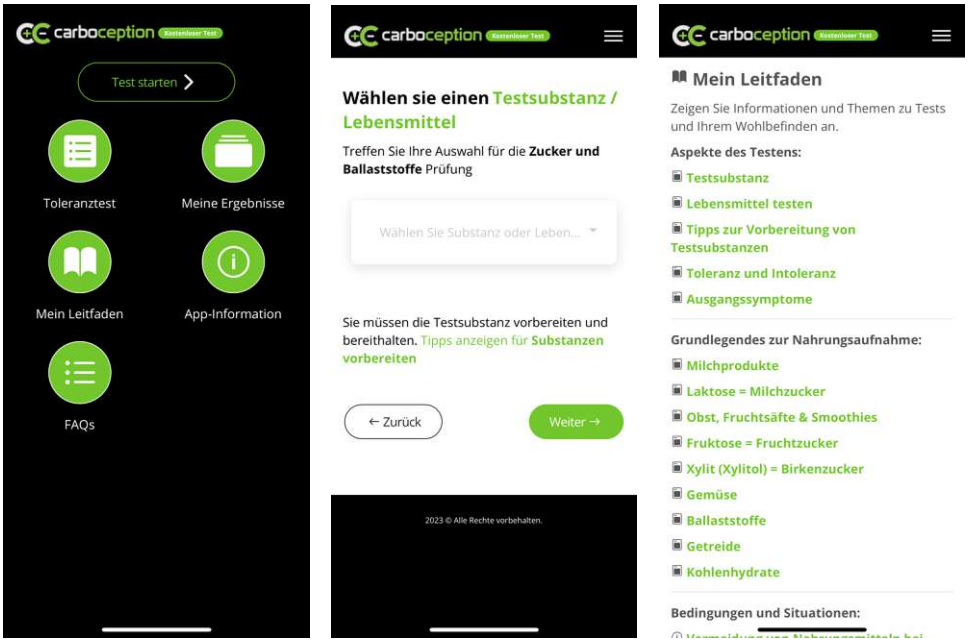


Figure 3.2: App *CarboCeption* [75]

3.1.3 Healthy Meals

Healthy Meals is an app that supports restaurants to identify food ingredients and food allergens in their menu offerings. This should help customers make healthier food choices and prevent people suffering from hypersensitivities from eating incompatible ingredients. In the app, the nutrient content of dishes is evaluated according to the Guideline Daily Allowances (GDA) for food servings and labeled using the Multiple Traffic Light (MTL) system. In this system, the nutrient content is rated with red, orange and green. Furthermore, the 14 food allergens stated by the EU legislative regulation are displayed in the restaurant dishes. The web app is shown in figure 3.3 [76].

3.1.4 Can I Eat That

Can I Eat That is a cloud app which has been developed by Makarevich et al. specifically for eating out since ordering in a restaurant is often a challenge for people with allergies or hypersensitivities. With the app, meals can be quickly and easily checked for incompatible ingredients. The country, the restaurant name and the name of the meal can be entered in a search query. This can be seen in figure 3.4. Furthermore, 14 different incompatible allergens can be selected, which should be avoided. As a result, the app shows the user whether the meal can be consumed. The data for this information is provided by three different sources: the restaurant directly, indirectly from the restaurant websites and the users themselves, who add data to the app based on their own experiences [77].

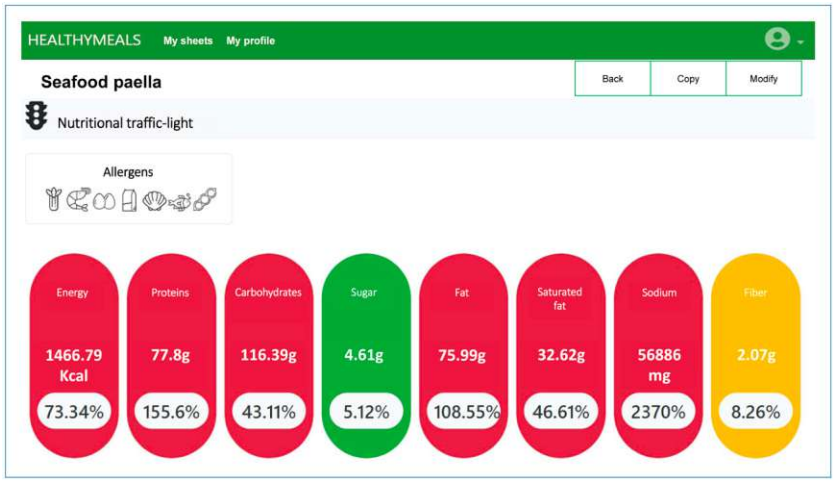


Figure 3.3: App *Healthy Meals* [76]

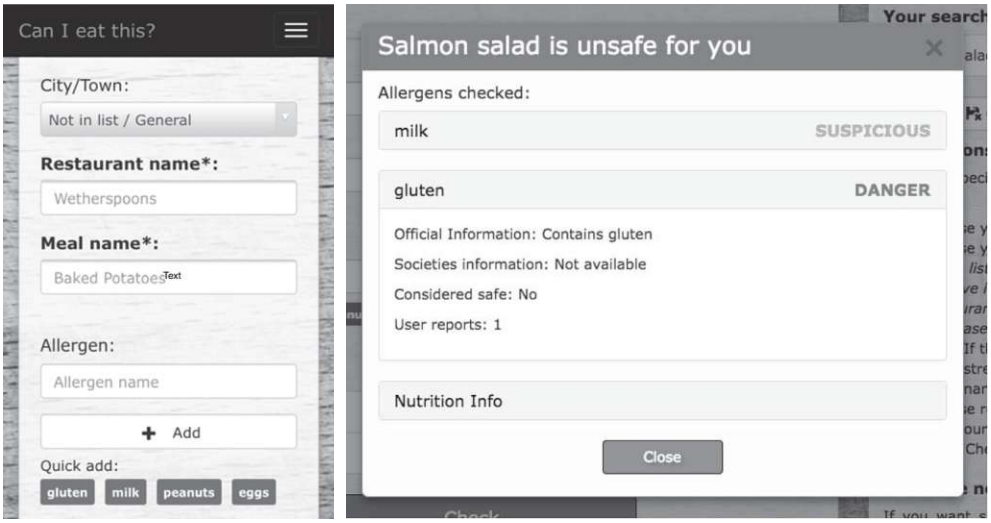


Figure 3.4: App *Can I Eat That* [77]

3.1.5 App for Celiac Disease

The mobile application developed by Altamirano et al. specializes in celiac disease. The focus lies on the management of a gluten-free diet from the perspective of the social environment of those affected. The app is intended to help individuals suffering from celiac disease as well as their social environment. The patient should be given a sense of safety and belonging through the use of the application. In the app, general and specific information can be shared on four aspects of lifestyle: social, emotional, food and wellness. This includes help in the area of socializing, traveling, eating at restaurants, mental health and symptoms. The mobile application can be seen in figure 3.5 [78].

Figure 3.5: App for Celiac Disease [78]

3.1.6 Histamine, Fructose & Co.

The app *Histamine, Fructose & Co.*, short *HI, FM & Co*, is an app that can be used after the diagnosis of a food intolerance (lactose, fructose, histamine, sorbitol, tyramine, FODMAPs, oligosaccharide, saccharose, salicylate). The app contains a detailed list of food products that are color-coded according to the user's intolerance. The own hypersensitivity can be determined in the filter function. The list of food products can be seen in figure 3.6. Each list entry has a background color, indicating the tolerance. There are four different colors: red, orange, yellow and green. Red means that the food is not well tolerated and green that it can be eaten without concerns. Orange and yellow are in the middle. It is possible to sort food products according to hypersensitivity through the filter function. Furthermore, when clicking on a food product, the app displays a detailed table of food ingredients, although this is only displayed in the PRO-version. The app also includes the option to create a shopping list or save own recipes and provides information about various food sensitivities [79].

3.1.7 ALL i CAN EAT

ALL i CAN EAT is an app for individuals suffering from lactose, fructose, histamine, gluten, sorbitol or salicylate sensitivity. The app also contains a color-coded food list according to the user's intolerance, which can be modified in the settings. Furthermore, it is possible to adapt one's preferences according to specific food categories. In the detailed overview of selected foods there is information on the food ingredients and the own tolerance of a product can also be specified. This can be seen in figure 3.7 [8].

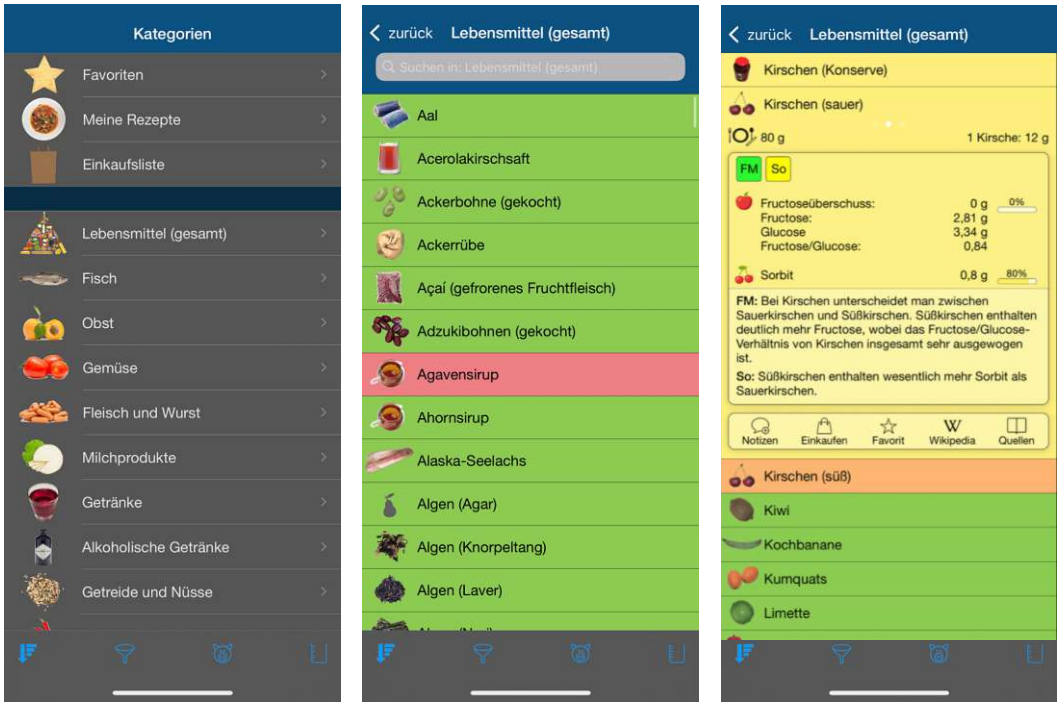


Figure 3.6: App *Histamine, Fructose & Co.* [79]

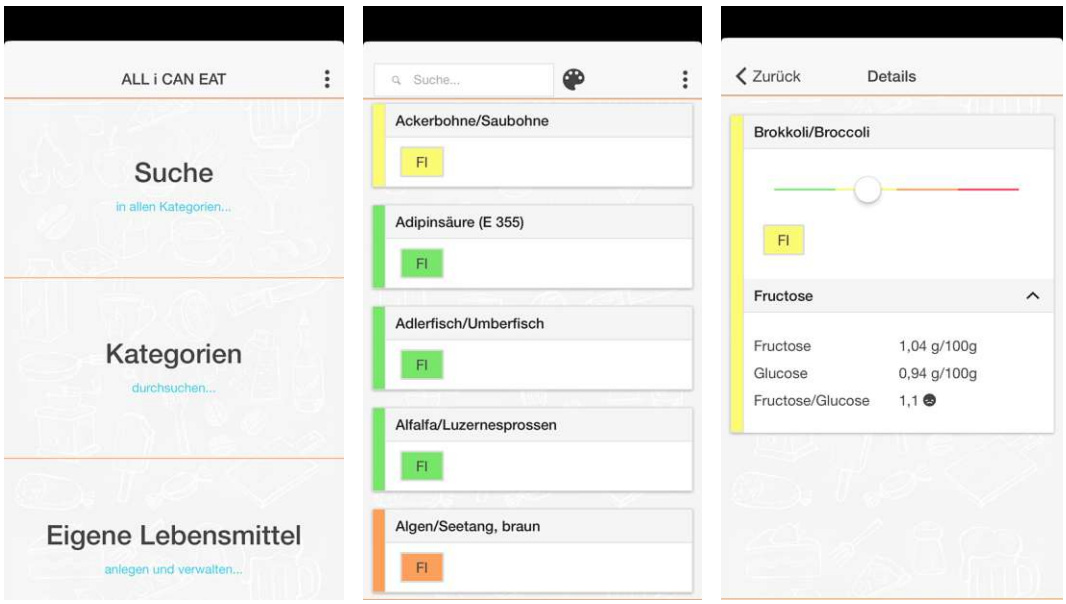


Figure 3.7: App *ALL i CAN EAT* [8]

3.1.8 MyHealthyGut

Dowd et al. have developed the *MyHealthGut* app for people with celiac disease. The app is designed to help users manage celiac disease and improve their gut health. The application can be seen in figure 3.8. It contains information about the disease itself and possible causes of gastrointestinal symptoms. Moreover, the application includes a list of foods that promote intestinal health. Furthermore, one's own diet and corresponding symptoms can be easily documented. The app additionally includes a meal plan for one day or seven days if an in-app purchase is made [80].

Figure 3.8: App *MyHealthyGut* [80]

3.1.9 FoodSwitch

FoodSwitch is an app designed by Dunford et al. for celiac disease and uses barcode scanning technology to scan food products. The app provides detailed information about the scanned products by using a large database of branded food products. Nutritional information about packaged foods can thus be presented to the user in a simple language and healthier alternative products are suggested where appropriate. The nutritional information is provided with the help of traffic light labels. The app also includes the GlutenSwitch functionality, for people suffering from celiac disease and those needing recommendations for gluten-free foods. The application can be seen in figure 3.9 [81].

3.1.10 Tioli

With *Tioli*, it is possible to scan the barcode of a food product to determine if it has been tolerated by other people with the same hypersensitivity. In the profile, one's own hypersensitivities can be specified. In general twelve hypersensitivities (histamine, lactose,

fructose, glucose, gluten, FODMAPs, sorbitol, salicylate, sulfite, oxalate, xylitol, protein) and three different diets (vegan, vegetarian, pescetarian) can be selected. Furthermore, it is possible to rate products according to one's own tolerance or to add new foods, should those not already exist. In addition, the app provides detailed information on selected food products. There is also the possibility of earning badges by completing tasks. An overview of already achieved tasks can be seen on the home screen of the app. This can be seen in figure 3.10 [82].

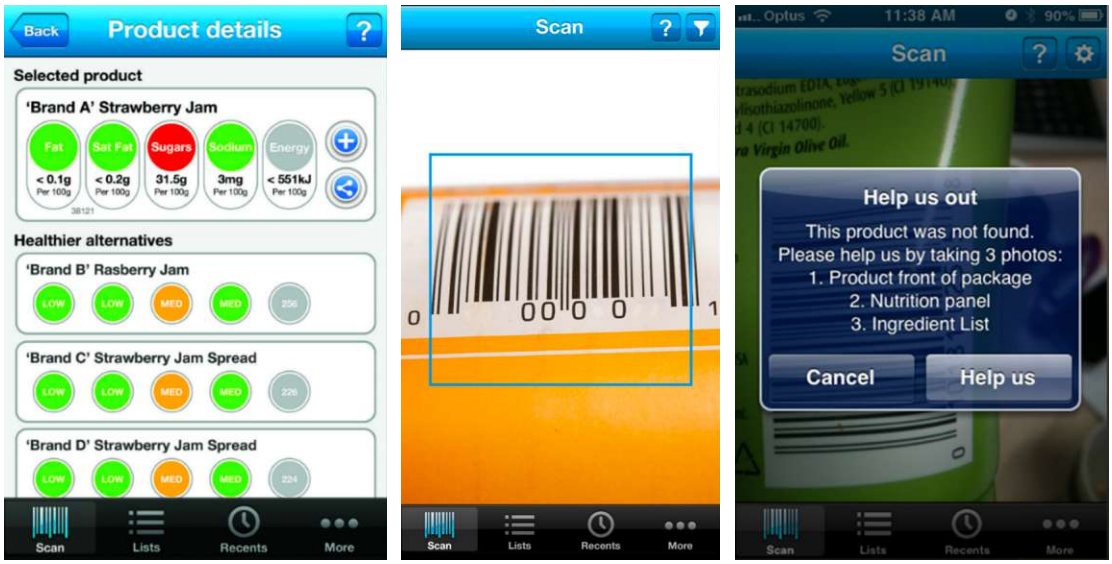


Figure 3.9: App *FoodSwitch* [81]

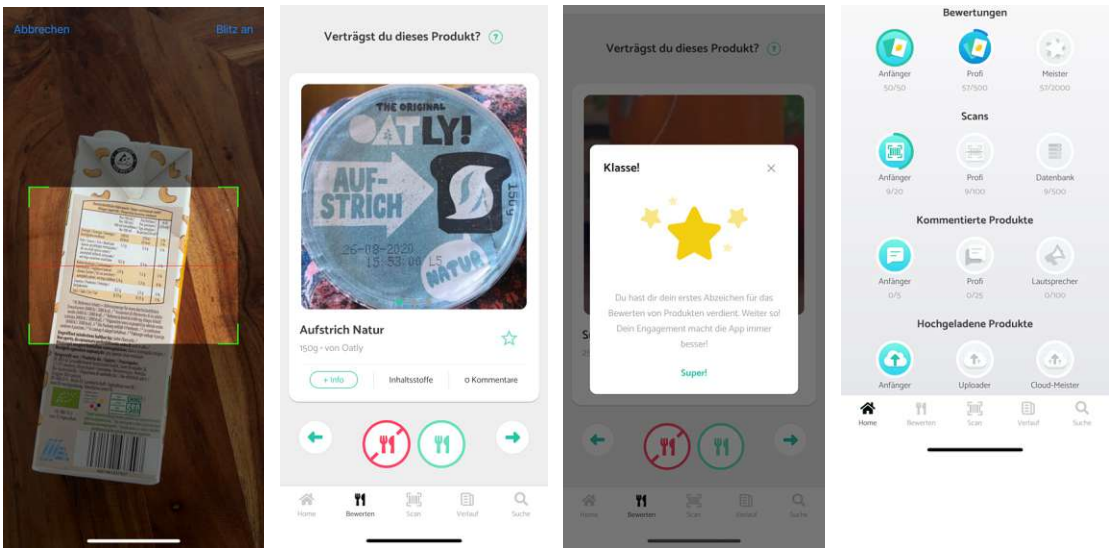


Figure 3.10: App *Tioli* [82]

3.1.11 HealthMe

HealthMe is a digital shopping assistant for all people who suffer from a hypersensitivity or allergy or who voluntarily want to avoid certain foods or additives. The app aims to facilitate shopping for compatible foods. When the app is launched, information about existing allergies or hypersensitivities has to be entered. It is also possible for the user to state certain foods or ingredients to which attention should be paid, such as fat-free, low-calorie or vegan products. By clicking on the camera symbol, the barcode of food products can be scanned. Detailed information about the food is subsequently displayed to the user. Different colors (red, yellow, green) communicate to the user whether the scanned product corresponds to a healthy diet. The app can be seen in figure 3.11 [10].

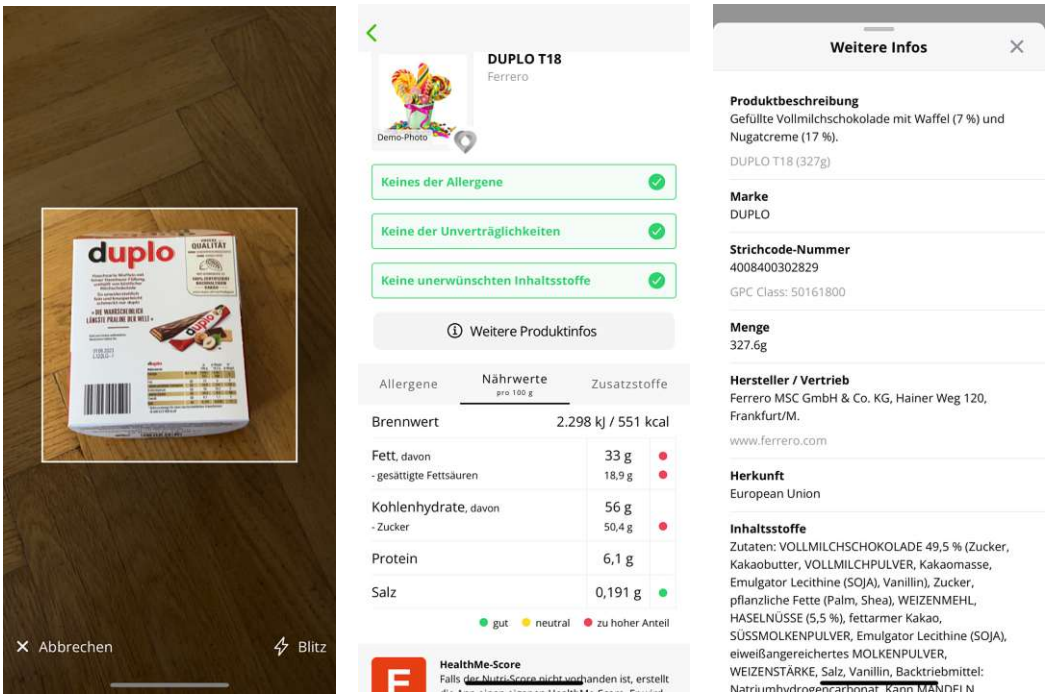


Figure 3.11: App *HealthMe* [10]

3.1.12 Intol

Intol is an app designed for several food intolerances (lactose, fructose, gluten, histamine, sorbitol, salicylate, glutamate). Furthermore, it can be used during pregnancy, when some food products or food ingredients should be avoided. In the settings, one's own hypersensitivities can be specified. With the app it is possible to scan the ingredients list of food products, as can be seen in figure 3.12. With the scanned information, the app subsequently generates a color-coded list with the ingredients (red, orange, yellow, no

color) according to the selected tolerance in the app. Intol also allows searching for certain ingredients in the ingredients list. The elements in the list are also color-coded [83].

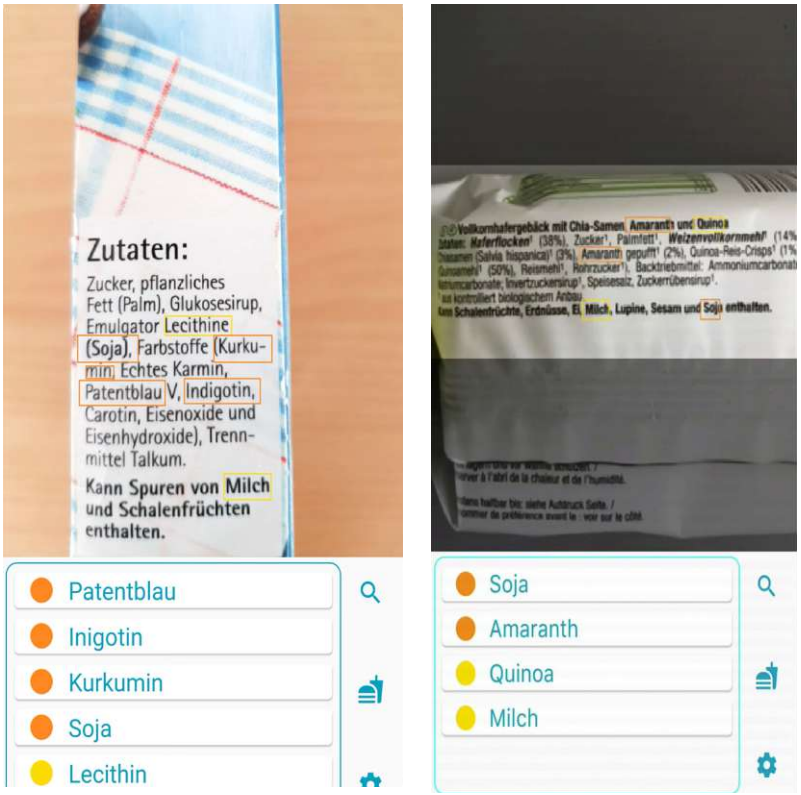


Figure 3.12: App *Intol* [83]

3.1.13 Frag Ingrid

Frag Ingrid is an app for humans suffering from fructose, lactose, sorbitol, histamine or gluten hypersensitivity or humans diagnosed with irritable bowel syndrome. One's own food intolerance can be stated in the "Setting & More"-menu. A special feature of the app is that it distinguishes between the different therapy phases. As can be seen in figure 3.13, it is possible to choose between the abstinence phase and the long-term diet when specifying the own hypersensitivity. The app contains a list of foods that are color-coded according to the tolerance of the user's hypersensitivity. When a food product is selected, more detailed information is displayed and it is possible to rate the products according to their own tolerance. Moreover, the possibility exists to see how other users tolerate the food by clicking on the "Community"-button. Furthermore, it is possible to enter one's own rating for foods. In the detailed view of food products, it is also possible to add the food to a favorites list. In addition, the app contains a news section allowing the user to receive news about food intolerances [9].

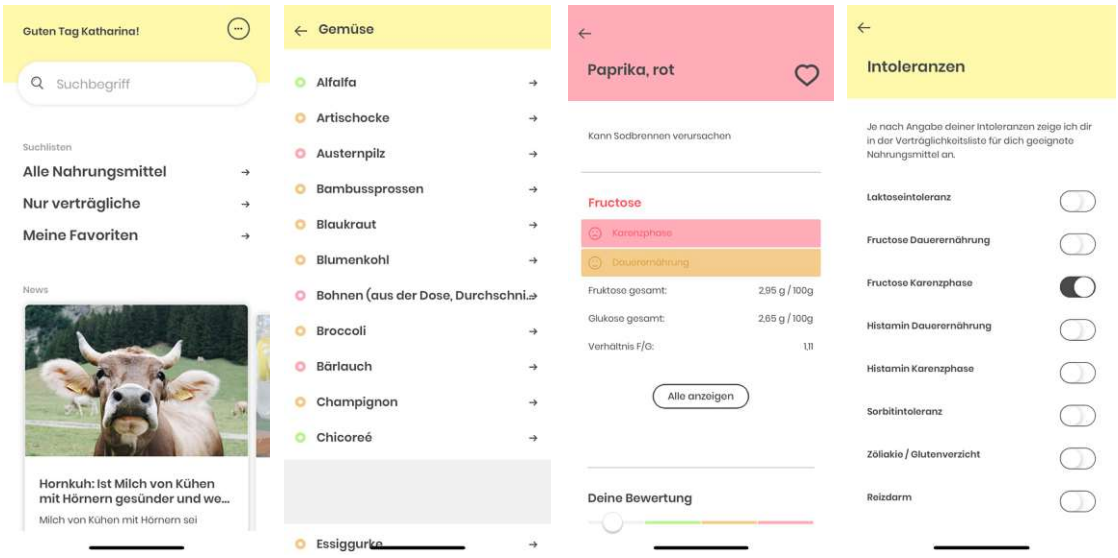


Figure 3.13: App *Frag Ingrid* [9]

3.2 Apps Specifically for Fructose Hypersensitivity

In this section, two apps are described that are specifically designed for humans suffering from fructose hypersensitivity.

3.2.1 Fructika

With *Fructika*, it is possible to search through a database of food products to find out if a product can be eaten when suffering from fructose hypersensitivity. When a product is selected, the app shows more detailed information about the tolerance, the fructose/glucose balance, contained sugars as well as the lactose and protein amount. Adding food products to "Favourites" is also possible. The fructose warning level can be adjusted to the own needs in the settings menu. The application is illustrated in figure 3.14 [84].

3.2.2 Fructose Guide

Fructose Guide contains only one function. With the app, it is possible to view a list of food products categorized into eight food categories. Categories like vegetables, fruit and drinks can be selected on the homescreen. In each of these categories, it is possible to filter for specific products. The food products themselves are color-coded in green, orange and red, which stands for "Safe to Eat", "Safe to Try in Moderation" and "Avoid". This can be seen in figure 3.15 [85].

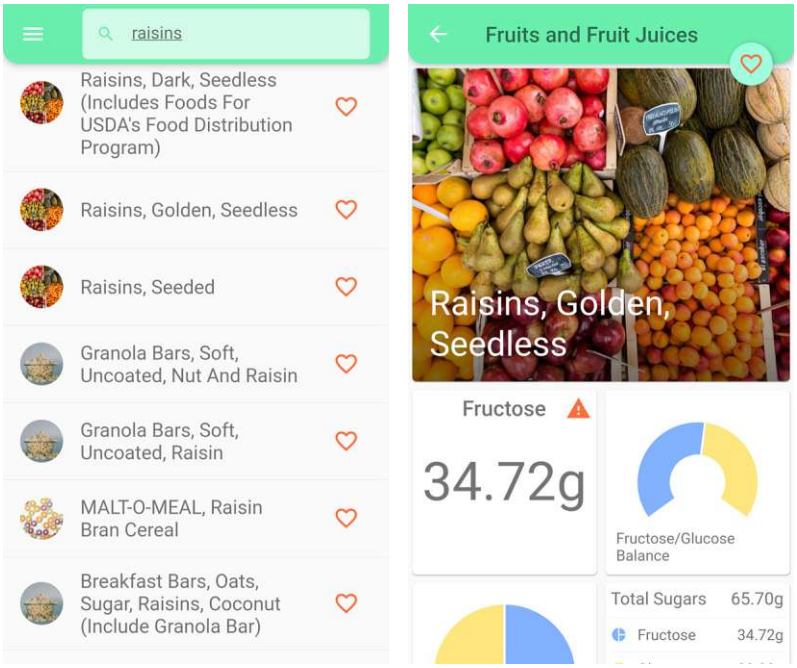


Figure 3.14: App *Fructika* [84]

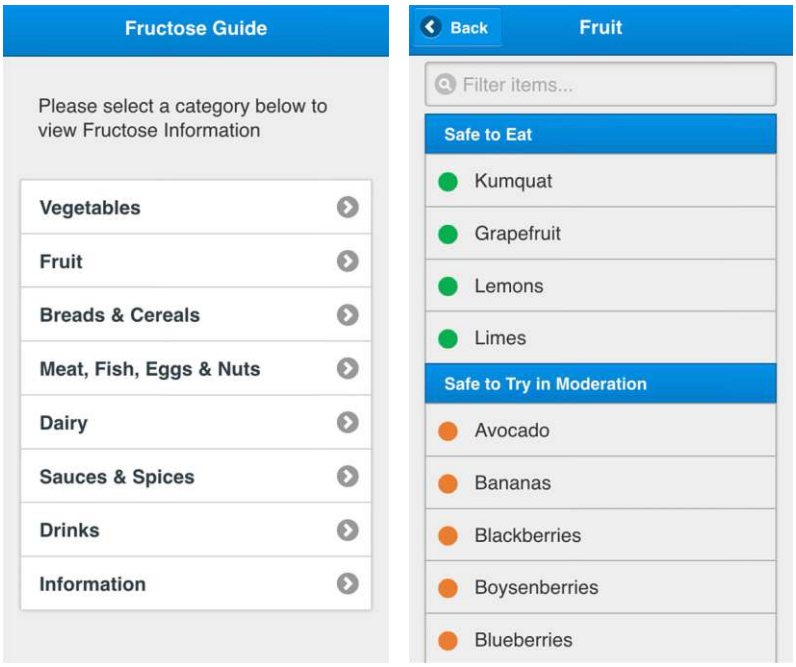


Figure 3.15: App *Fructose Guide* [9]

3.3 Summary and Comparison

A total of fifteen apps have been described and analyzed in more detail. The goal of the applications is to support individuals who face problems with their food intake. The approaches vary substantially in some cases. The first two apps described, *BesserEsser* and *CarboCeption*, focus on the diagnosis of food intolerances. While the former provides the diagnosis based on the analysis of the user's dietary and symptom protocols, the latter offers its own hypersensitivity test, which is performed step by step within the app itself. All of the other apps analyzed have their area of application in the support of individuals after the diagnosis of a food hypersensitivity. *Frag Ingrid* is the only app analyzed offering the function to choose between abstinence phase or long-term diet.

Eleven of the fifteen apps described provide support for humans suffering from fructose hypersensitivity. Assistance for lactose hypersensitivity is also well-represented among the applications mentioned. Seven of the fifteen apps assist with this specific food intolerance. Many apps described offer support for sorbitol, gluten and histamine hypersensitivity. Among the applications, the app *HealthMe* stands out by its range of covered food intake problems. It provides assistance for a lot of different food intolerances and allergies. Furthermore, certain ingredients, such as sweeteners and flavor enhancers that should be avoided, can be specified in the app. The application area of the other applications is more narrow compared to *HealthMe*.

More than half of the apps that can be used after diagnosis provide color-coded food lists. Most of them use red, yellow, orange and green as colors to indicate the level of tolerance. Furthermore, many applications provide detailed information on the ingredients of a selected food product. This includes, for example, detailed information on the fructose and glucose amount or the fructose/glucose balance. For some apps, a rating based on their own tolerance of a food product can be added in addition. The possibility to add personal notes and/or to create a list of favorites can be found in six apps. *Frag Ingrid* is the only app that provides a news section with new findings on food intolerances. Moreover, only *FoodSwitch* contains the function of suggesting alternatives for food products. A meal plan is only offered in *MyHealthyGut*.

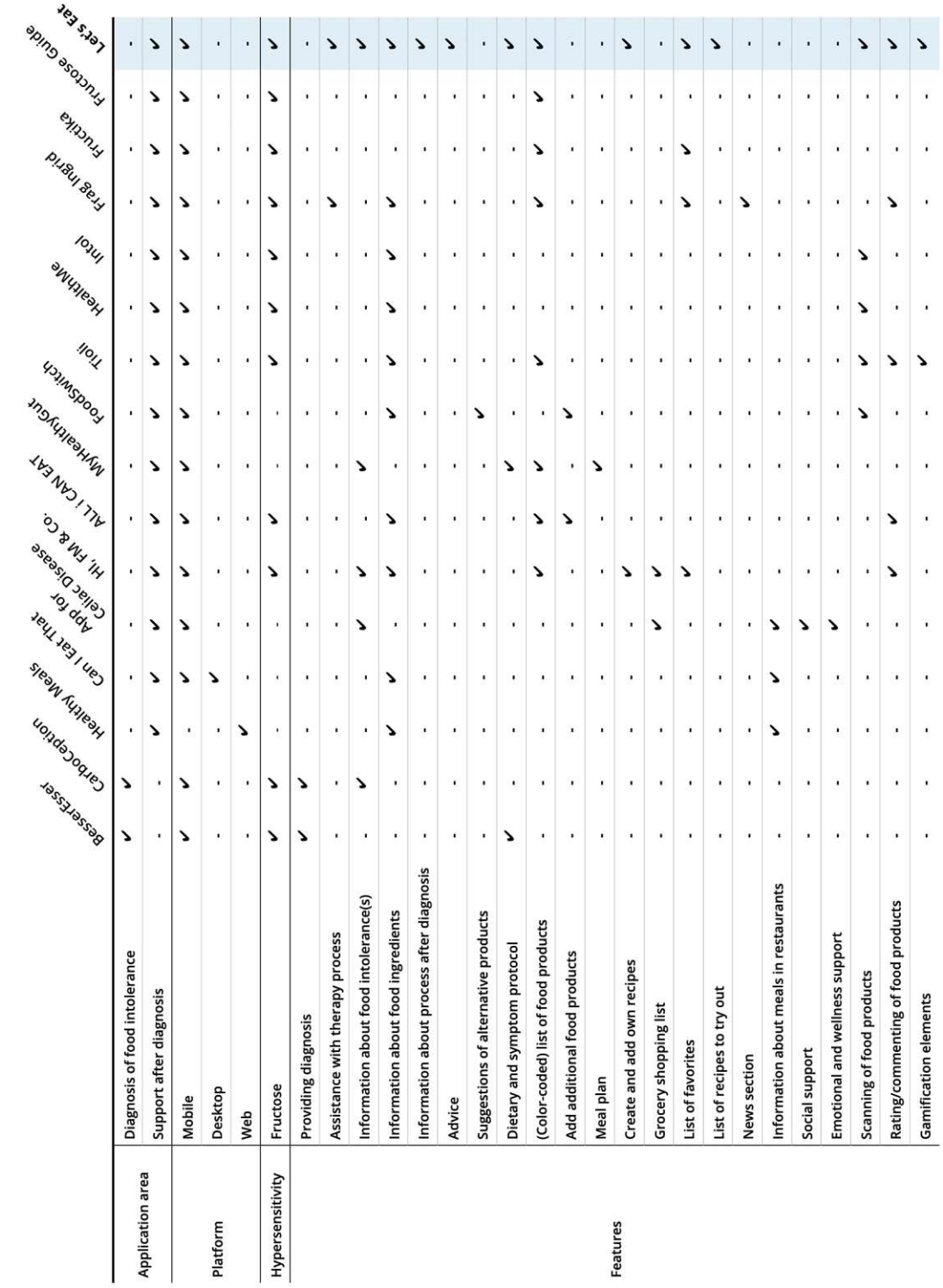
Four apps provide the opportunity to scan food products. In *FoodSwitch*, *Tioli* and *HealthMe*, the barcode is scanned to receive more detailed information. In comparison, *Intol* scans the ingredient list of the food in order to find out which ingredients are not tolerated or should be avoided. All four apps use the smartphone's camera for scanning.

Out of all apps examined, only one uses gamification elements. In *Tioli*, tasks can be solved to receive badges.

In the following figure 3.16, an overview of the apps described is illustrated. As can be seen, these mobile apps offer support in various life situations, but none of them contains an all-in-one solution. For example, none of the apps described offers assistance in all of the different therapy phases and, at the same time, includes a dietary and symptom protocol, although this would be enormously helpful, especially in the elimination phase,

as already described in section 2.3.2. The use of many different functions requires the use of several apps at the same time, which can be confusing and cumbersome. In general, fundamental information about the therapy of hypersensitivities and direct knowledge transfer is lacking among the apps analyzed. This means that a significant amount of prior knowledge is required to use the applications. Above all, serious gaming and gamification elements are absent in almost every app for adverse food reactions.

The application concept created for the purpose of this thesis received the name *Let's Eat* and is also included in the following table for better comparability. The implementation of the app will be explained in chapter 4. Since the developed version only contains a reduced amount of functions due to the limited scope of this master thesis, the mockup was referred to for comparison. A unique feature of the implemented app represents the conceptualization as an all-in-one solution. The sum of functions that were only available by using several apps for food intolerances at the same time are now integrated into one single app. Moreover, the application is one of the few apps designed exclusively for fructose hypersensitivity, which means that special consideration is given to the difficulties associated with this specific food intolerance. Furthermore, the app helps to assist from the moment of diagnosis. In that manner, the app is intended as a companion to support in the first steps after the diagnosis and also helps in the long term following the diet. The application contains information about fructose hypersensitivity and explains how to proceed after the diagnosis. Helpful suggestions collected from people affected are intended to facilitate dealing with fructose hypersensitivity and to provide long-term support. In addition, it is possible to define whether one is currently in the abstinence phase or in the long-term diet. Another notable feature of the implemented app is a high degree of customizability. Elements can be customized according to personal preferences and tolerance. Products in the food list can be rated through a color scheme, whereas recipes can be scored 1-10. In addition, the app offers the function to add personal notes, both in the dietary and symptom protocol as well as in the recipes section. Another notable feature is the integrated gamification concept, which is intended to motivate the user to stick with the restricted diet. On top of that, the dietary and symptom protocol represents an innovative concept that integrates playful elements.



		BesserEsser	CarboCeption	Healthy Meals	Can I Eat That	App for Celiac Disease	Hi, FM & Co.	ALL I CAN EAT	MyHealthyGut	FoodSwitch	Tiloli	HealthMe	Intoi	Frag Ingrid	Fructika	Fructose Guide	Let's Eat
Application area	Diagnosis of food intolerance	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Support after diagnosis	-	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Platform	Mobile	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Desktop	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-
	Web	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypersensitivity	Fructose	✓	✓	-	-	-	✓	✓	-	-	✓	✓	✓	✓	✓	✓	✓
Features	Providing diagnosis	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Assistance with therapy process	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	✓
	Information about food intolerance(s)	-	✓	-	-	✓	✓	-	✓	-	-	-	-	-	-	-	✓
	Information about food ingredients	-	-	✓	✓	-	✓	✓	-	✓	✓	✓	✓	✓	-	-	✓
	Information about process after diagnosis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
	Advice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
	Suggestions of alternative products	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-
	Dietary and symptom protocol	✓	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	✓
	(Color-coded) list of food products	-	-	-	-	-	✓	✓	✓	-	✓	-	-	✓	✓	✓	✓
	Add additional food products	-	-	-	-	-	-	✓	-	✓	-	-	-	-	-	-	-
	Meal plan	-	-	-	-	-	-	-	✓	-	-	-	-	-	-	-	-
	Create and add own recipes	-	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	✓
	Grocery shopping list	-	-	-	-	✓	✓	-	-	-	-	-	-	-	-	-	-
	List of favorites	-	-	-	-	-	✓	-	-	-	-	-	-	✓	✓	-	✓
	List of recipes to try out	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	✓
	News section	-	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-
	Information about meals in restaurants	-	-	✓	✓	✓	-	-	-	-	-	-	-	-	-	-	-
	Social support	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-
	Emotional and wellness support	-	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-
	Scanning of food products	-	-	-	-	-	-	-	-	✓	✓	✓	✓	-	-	-	✓
	Rating/commenting of food products	-	-	-	-	-	✓	✓	-	-	✓	-	-	✓	-	-	✓
	Gamification elements	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-	✓

Figure 3.16: Comparison of apps for food hypersensitivities

CHAPTER 4

Results

In this chapter, the practical part of this thesis will be presented. First, information about the phases and the participants will be given. Then, the theoretical part will be reflected by addressing and analyzing the most important aspects. Subsequently, the conduction of the interviews performed with humans suffering from fructose hypersensitivity will be displayed. Requirements translated from the information obtained in the interviews will be described. Moreover, the iterative creation process of the mockup and the fundamental idea behind the design will be illustrated in detail. Subsequently, the implementation of the finished prototype, including the technical aspects and the selected functions, will be described. Finally, the conduction of the user testing, consisting of the "Thinking aloud" method and usability benchmarking of the implemented application, will be explained and the results will be presented.

4.1 Phases Overview

The practical part consists out of 5 phases. *Phase 1* includes the reflection of the theoretical part of the work. Essential aspects will be reviewed and analyzed. Structured interviews were conducted during *Phase 2* to determine the user requirements for an application to support people suffering from fructose hypersensitivity. The answers received were summarized and the most significant aspects were identified. Based on the results, requirements were formulated and used to create a mockup. The creation process was done within *Phase 3*. The realization of the mockup was performed in an iterative process. Feedback was obtained after each version, followed by a revision of the prototype. Within *Phase 4*, a prototype was implemented that could be used on a physical device. *Phase 5* describes the performed user testing. An overview of the conducted phases together with the method used and an explanation can be found in table 4.1

Phase ID	Title	Goal
PH-1	Reflection	Reflection on the steps already taken and summary of the most relevant aspects
PH-2	Interview	Identification of the user requirements for application to support people suffering from fructose hypersensitivity
PH-3	Mockup	Creation of a prototype that users can test and on which feedback can be obtained
PH-4	Implementation	Implementation of the prototype that can be used on a real device
PH-5	User Testing	Testing of the app to determine existing difficulties

Table 4.1: Overview of phases

4.2 Participants

The following table 4.2 provides an overview of the participants involved in the creation process of the prototype. 28 people participated in total, 21 of which were female and 7 male. 18 out of all the participants suffer from fructose hypersensitivity. Two participants work in the field of nutrition. One of them was interviewed as a person affected by fructose hypersensitivity and as an expert. Detailed information about both experts can be seen in the table 4.3.

4.3 Phase 1: Reflection

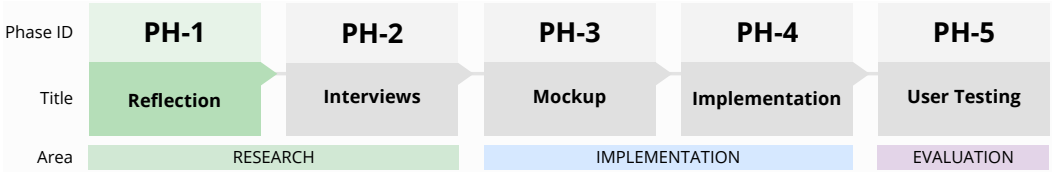


Figure 4.1: Phase PH-1: Reflection

During the literature research, various sources were examined to understand how fructose hypersensitivity has an impact on life and how it can be treated. A three-step procedure is recommended as a therapy consisting of an elimination phase, a reintroduction phase and a long-term diet. Within the first two phases, various foods must be avoided entirely or can only be eaten in small amounts. Numerous food lists can be found on the internet with detailed information on the foods' content of fructose and glucose and their tolerance for people with fructose hypersensitivity. As the literature research has shown, the tolerance of food varies from person to person and depends on various factors. This was described in section 2.3.3. In particular, it is influenced by the duration the food remains in the stomach and the combination of different products consumed. Moreover,

foods containing fructose are usually better tolerated when fat, protein, fiber or glucose are consumed at the same time. A higher amount of glucose than fructose in a food product increases the tolerance. These aspects lead to a challenging treatment of fructose hypersensitivity. As already discussed in section 3.3, existing apps have limitations or missing functions. Interviews will provide more insight into the needs of people with fructose hypersensitivity and how to best support affected individuals in therapy.

Participant ID	Gender	Age	Fructose malabsorption	Highest level of education	Phase ID
P1	female	30	✓	University	PH-2
P2	female	41	✓	A-Level	PH-2
P3	female	43	✓	A-Level	PH-2
P4	female	26	✓	A-Level	PH-2, PH-3c
P5	female	28	✓	University	PH-2
P6	female	49	✓	A-Level	PH-2
P7	female	32	✓	University	PH-2
P8	female	23	✓	University	PH-2, PH-3c
P9	female	33	✓	A-Level	PH-2
P10	male	23	✓	University	PH-2
P11	female	53	✓	University	PH-2, PH-3c
P12	male	28	✓	University	PH-2
P13	female	22	✓	A-Level	PH-2
P14	male	29	✓	University	PH-2
P15	male	24	✗	University	PH-3a-b, PH-5a
P16	male	24	✗	University	PH-3a-b, PH-5a
P17	female	23	✗	A-Level	PH-3a-b, PH-5a
P18	female	25	✗	University	PH-3a-b, PH-5a
P19	female	27	✓	University	PH-3c
P20	female	27	✓	A-Level	PH-3c
P21	female	23	✗	University	PH-3c
P22	female	24	✗	University	PH-5b
P23	male	26	✓	University	PH-5b
P24	female	24	✗	University	PH-5b
P25	female	59	✗	University	PH-5b
P26	male	22	✗	A-Level	PH-5b
P27	female	22	✗	University	PH-5b
P28	female	23	✓	University	PH-5b

Table 4.2: Overview of all participants

Participant ID	Gender	Fructose malabsorption	Working area
P11	female	✓	Nutritionist, focus on nutrition coaching
P21	female	✗	Dietologist, focus on nutritional therapy and consultation

Table 4.3: Overview of experts

4.4 Phase 2: Qualitative Interviews

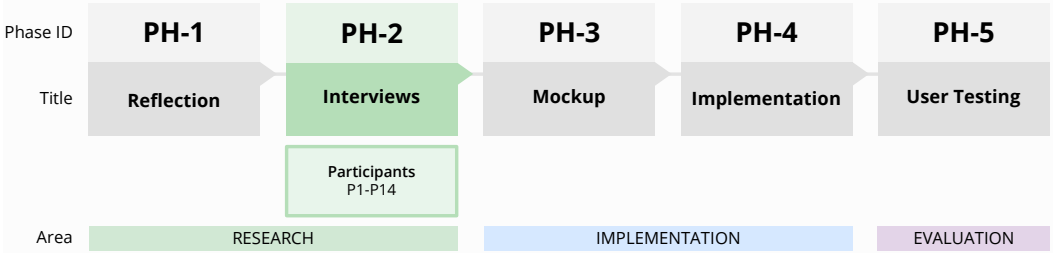


Figure 4.2: Phase PH-2: Interviews

Structured interviews were conducted to identify the requirements for an application in order to support people with fructose hypersensitivity. This method represents an traditional techniques already described in section 2.4.4. The aim was to determine the functionalities needed for the prototypical implementation.

In selecting individuals for the interviews, the focus was placed on people aged 18-60 suffering from fructose hypersensitivity. The diagnosis must have been received at least two months before participating in the interview. This should ensure that a certain fundamental knowledge about fructose hypersensitivity was given. To recruit people from this particular target group, acquaintances were asked and posts in certain forums for people with fructose hypersensitivity, like the Facebook group "Fructoseintoleranz Hilfe und Erfahrungsaustausch" [86], were written. A total of 14 people were interviewed. The interviews were generally conducted in German, as all participants were from German-speaking countries.

4.4.1 Preparation

In the beginning, an interview guide was created for the conduction of the interviews. This was elaborated in an iterative process. After obtaining feedback in written form, the interview guide was revised and additional questions were added. The guide is divided into four sections: demographic data collection, fructose hypersensitivity, apps for fructose hypersensitivity or diet in general and a conclusion. Since one of the interviewees suffers from fructose hypersensitivity and works as a nutritionist herself, an additional

section with questions for the expert was added. A total of 28 questions were formulated for all interviewees and four additional ones were created specifically for the nutritional expert. The interview guide can be seen in appendix A. In general, an interview guide is a document that guides a researcher through the interview process and serves as a support. The interview guide contains the following elements: the questions to be asked, information, notes, or even reminders that are relevant to the interview. For example, a reminder would be to remember to record the interview [87]. According to Arsel, an interview guide should contain three components: a brief introduction that includes, among other things, a description of the research project and an explanation of the interview process. A component that clarifies consent to participate and, as a third element, the prepared interview questions [88]. In addition to the interview guide, a consent form was prepared.

4.4.2 Execution

Due to local differences and for efficiency reasons, all interviews were conducted online. Zoom was chosen for the online interviews since the program already provides a function for recording. However, due to technical problems on the side of the interviewees, two interviews had to be conducted via telephone. Before the interview was carried out, the consent form was sent to the interview participants and unclear questions, if some existed, were clarified. The interview started with a greeting and a thank you for the time taken and for sending the consent form. This was followed by a brief discussion of the process and the approximate interview length. Then, if there were no further questions on the side of the interviewee, the interview questions were asked. The questions were based on the interview guide, which - as already mentioned - was divided into five sections, four of which were posed to all of the participants and an additional one for the expert. The sections will be explained in more detail below. The concrete questions can be found in the appendix A.

1. As a first step, demographic data on age, gender and highest achieved school education was collected.

2. In the second section of the interview, the interviewees were asked questions about their own fructose hypersensitivity. The first question referred to the type of fructose hypersensitivity and the date when the fructose hypersensitivity was diagnosed. Furthermore, the interviewees were asked how they noticed the food intolerance. These questions mainly served as an ice breaker and to loosen up the conversation. This was followed by questions about the procedure after the diagnosis and how the person's diet changed due to the hypersensitivity. These questions asked had the purpose of getting a better understanding of the individual food intolerance and of understanding the difficulties people face after they received the diagnosis. This was important to figure out how individuals suffering from fructose hypersensitivity can be supported. The last question in this section was to ask interviewees about their lifehacks for eating certain foods containing fructose.

3. The third section addressed the apps for fructose hypersensitivity and for nutrition in general. The question was asked whether apps for the support of fructose hypersensitivity had been or were currently in use. If the answer to the latter was yes, the participants were interviewed on specific details about the app, for example, which functionalities served their needs best and which were not useful for them. If the question about the use of general apps for nutrition was answered with yes, more detailed questions regarding the functions of the general apps followed. On the one hand, these questions aimed to find out which functionalities of already existing apps should also be implemented into the app prototype. On the other hand, the aim was to determine which additional functions, which may not have been realized within current applications on the app market yet, are required by or desired by the interviewees. It was also substantial to figure out which other aspects were of particular relevance to the interviewees.

4. The fourth section contained questions specifically for the nutritional expert, including questions about the most significant difficulties patients face from the expert's point of view and how she tries to help her patients to deal with the food intolerance. These questions were important in determining which aspects of the treatment of fructose hypersensitivity are fundamental from an expert's point of view.

5. Finally, the questions were asked if the interviewees had any further comments or ideas they would like to share and if they would be willing to test the finished prototype. This was followed by a goodbye.

4.4.3 Interview Results

A total of 14 individuals were interviewed, 11 of whom were female and 3 male. All interviewees were diagnosed with fructose malabsorption. All of them have at least A-Level and 8 persons hold a degree from a university (Bachelor/Master). An overview of the interview participants (*P1-14*) is shown in table 4.2. *P11* received questions as a person affected and as an expert since she is diagnosed with fructose hypersensitivity and works as a nutritionist. The following summarizes the results of the interviews. The interviews were analyzed using qualitative content analysis according to Mayring [11].

Diagnosis

At the beginning of the interview, the interviewees were asked when they had been diagnosed with fructose hypersensitivity or how long they had been aware of the intolerance. Eight participants (*P2-P8, P11*) indicated that they had already been experiencing symptoms for a long period, but the diagnosis of fructose hypersensitivity had been received much later. Almost all of these eight participants had experienced the issue that other diseases or triggers of the symptoms had been suspected at first. Therefore, the tests for food intolerances had been performed much later. This had had the impact that other intestinal diseases, such as irritable bowel syndrome, had been misdiagnosed. As a result, the diagnosis of fructose hypersensitivity had taken five years after the

first symptoms occurred in the case of person *P2* and even seven years for interview participant *P6*. The remaining six interview participants (*P1, P9, P10, P12-P14*) had received the diagnosis of their food intolerance relatively quickly in comparison. Within a few months, the diagnosis had been obtained.

Procedure After Diagnosis

During the interview, one point of interest was how the interviewees had proceeded after the diagnosis of their food intolerance. Six interviewees (*P2, P4, P6, P9, P11, P12*) stated that they had sought nutritional counseling due to their fructose hypersensitivity. However, four of these interviewees (*P2, P6, P11, P12*) said they had not found their attended session(s) very helpful. *P12* answered that he had visited two different nutritional counselors since the first counseling had not provided the information and support he had hoped for. Interviewees *P5* and *P14* had received counseling directly after the food intolerance test. However, *P5* had not perceived the counseling as sufficient. As a result, the persons concerned had done a lot of research on their food intolerance themselves. Books and reading on the internet had been used as sources of information. The six other interviewees (*P1, P3, P7, P8, P10, P13*) had only obtained information on their own or had received no further help from specialists apart from an information sheet that had been handed out directly after the diagnosis.

All persons interviewed had undergone the three-stage therapy in its basic outline. However, *P6*, *P7* and *P11* stated they had not adhered strictly to the abstinence phase since some products containing fructose had remained in their diet during this phase. *P11* conducted the 2g method during the first therapy phase. With the 2g method, affected individuals eat a maximum of 2g of fructose per day. *P4*, *P8* and *P12* also reported that they had kept food diaries to gain a better overview of the foods and their complaints. In general, many participants said that changing their diet had been a very challenging and time-consuming process, as one has to try many foods in order to find out which type of food is tolerated and which is not. Food lists can give an orientation, but one's own tolerance varies significantly from person to person. *P9* stated that she could only eat certain foods containing fructose during lunchtime and in the evening. As an example, the interviewee mentioned bananas. Eating the fruit in the morning would not be tolerated well. The combination of different foods is also decisive for tolerance. Seven people (*P1, P2, P4, P7, P12-P14*) said that they tolerated fructose much worse in stressful times. This makes the diet even more difficult. *P12* also mentioned that he tolerated fructose worse when thinking about what he may and may not eat all the time. The worry about eating the "wrong" food or food that is not tolerated causes additional stress for the interviewee during the meal itself, which leads to poorer tolerance.

Change of Diet

All interviewees except *P10* stated they had paid much more attention to their diet after they had received their diagnosis. On the one hand, this means that they avoid many products containing fructose, especially if the fructose amount is very high. For

example, a high amount of fructose can be found in numerous beverages and sweeteners like fruit juices or honey. On the other hand, people follow a much more conscious diet. *P4* and *P11* try to eat as gut-friendly as possible. The better the stomach feels, the more fructose can be tolerated. Both interviewees also make sure to eat as few highly flatulent foods as possible. *P4* also stated that she gave a closer look at the fructose/glucose ratio of products. A balanced ratio or more glucose helps her tolerate fructose in a better way. In the opinion of *P11*, an essential aspect of fructose hypersensitivity is fundamentally changing the diet and not just omitting individual products or replacing them with others. *P10* pays little attention to the fructose content in his diet because the interviewee currently has no symptoms.

Greatest Difficulties

In general, fructose hypersensitivity can be very life-restricting. A fundamental problem with the food intolerance is detecting what explicitly triggers the symptoms. This is because most of the time, not just one food is eaten unprocessed, but cooked and in combination with other foods. *P1* also stated that generally, he founds it difficult to determine which meal caused the symptoms, whether it was, for example, lunch or dinner, since the symptoms do not always occur immediately after eating. For *P3*, the biggest difficulty was not being able to eat without thinking. Getting a quick snack in the supermarket, like an apple, is no longer possible for her due to the food intolerance. *P5* stated that her food intolerance concerned not only raw products but also manufactured products. In the case of fruits, they can be found in fruit cakes, fruit yogurt, dried fruit, fruit muesli and many other products. As a result, many interviewees experienced the problem that they no longer knew what food they could buy and cook on a daily basis. *P9* also addressed the difficulty of maintaining a healthy diet because most fruits and vegetables were no longer tolerated. In addition, a restricted diet has a significant impact on social life. Whether going out to eat with friends, being invited for dinner or grabbing something to eat during lunch break, these situations can be very challenging for people with fructose hypersensitivity. Not being able to eat everything due to the intolerance is still not understood by most people, which means that in many cases, one is seen as complicated or picky. Having to ask for the ingredients can also be unpleasant, especially when many side dishes or ingredients have to be left out. Since fructose hypersensitivity affects so many food products, it is exhausting and tedious having to explain which foods should be avoided in the meal so that the food is tolerated. The fact that other people have to adapt themselves to the person suffering from fructose hypersensitivity is generally seen as an unpleasant situation.

Advice From People Affected

The interviewees *P1, P7, P8* and *P11* stated that they took pills specifically for fructose hypersensitivity. These try to help tolerate fructose better and are taken before the fructose-containing meal. *P1, P2* and *P4* each had tricks for still being able to enjoy the taste of garlic. One possibility is to insert garlic into oil for some time and then

use the garlic-flavored oil for cooking. Another method is to cook the clove of garlic with the other ingredients and then remove it after cooking. *P2* has also found a way to substitute vanilla yogurt: instead of buying ready-made vanilla yogurt, she uses regular yogurt and adds vanilla baking flavor. For cocoa, instead of using ready-sweetened cocoa powder, the interviewee just uses baking cocoa, mixes it with cinnamon and adds milk to it. *P4* has shared the tip to consume fructose with milk products or curd, as she tolerates fructose better with it. Participant *P7* increases the tolerance of fructose by eating glucose-containing products. *P8* eats five smaller meals daily instead of three large ones. As a general tip, *P5, P9* and *P12* said that they did not eat fructose on an empty stomach since fructose is better tolerated in this case. A well-tolerated food product should be consumed before eating fructose-containing foods. *P4, P13* and *P14* also stated that they paid particular attention to the diet, especially during stressful times, because fructose is tolerated worse during such periods. *P6* also provided the tip to eat proteins and fat with fructose to increase tolerance. This advice has already been described in section 2.3.3.

Feedback on Existing Apps

Eight interviewees (*P3, P6-P9, P11, P12, P14*) currently use an app for their fructose hypersensitivity or have already used an app in this context before. *P4* said that she had searched for an app but had not found a suitable one and others that had looked helpful had to be purchased. In general, she would have been willing to pay for an app, but the trial period of tried-out apps had been too short to test them extensively. *P4* said that, especially for apps in the context of fructose hypersensitivity, a test phase over an extended period was needed. A test period of, for example, two days was not sufficient. Six interviewees (*P1, P2, P4, P5, P10, P13*) had never used an app in the context of their food intolerance before. *P1* stated that she did not have a smartphone at the time of her diagnosis and, therefore, she had had no opportunity to use one. Six interviewees (*P3, P7, P8, P9, P11, P12*) had installed the *Frag Ingrid* app on their smartphone or downloaded it at least at some point in time. *P7* said that she used both the *Frag Ingrid* app and the *HI, FM & Co* app. Both apps contain food lists, but different tolerances are sometimes given for certain products. Therefore, the person used both apps so that if symptoms appeared, she could compare both lists and determine what might have caused the symptoms. The participants *P6* and *P14* had used an app for fructose hypersensitivity before but did not remember the name.

Regarding the functions of the *Frag Ingrid* app, five interviewees (*P3, P7, P8, P9, P11*) stated that they mainly used the food list within the app, which is color-coded according to the tolerance of the user's hypersensitivity. The news section had never been used by most of them. *P3* stated that the food list with the traffic light system served as a rough overview to check which food products could be eaten. However, the food lists were not completely accurate, as the tolerance was sometimes indicated differently. This was also stated by *P7, P8, P9* and *P11*. The given colors indicating the tolerance are to be seen as guide values since the tolerance can vary between different individuals. *P3*

appreciated the possibility of seeing how other people with the same food intolerance had rated certain food products. For individual products, it is possible to rate the tolerance independently. However, *P9* declared that she did not like this function. She furthermore mentioned that she shares the app with her child (who equally suffers from fructose hypersensitivity). Since there is no possibility to add another profile, *P9* could not use this function because both tolerate certain foods differently. The differentiation between the abstinence phase and long-term diet was perceived as very useful from *P3*. *P9* said that the *Frag Ingrid* app was quite complicated to use and that an additional function to create a list of favorites or preferred foods would be helpful. It has to be mentioned that this function, as described in section 3.1.13, already exists. The person had apparently not discovered it up until the time of the interview.

Five interviewees (*P1, P4, P8, P9, P13*) had used apps for other areas within the nutrition context before. *P1* had used the *Monash University FODMAP diet* app [89] once, as the person also suffered from other intolerances. The interview participants *P4, P8, P9* and *P13* had tried apps for counting calories or tracking other nutritional values. In this context, *P9* said an overview of the fructose intake would be beneficial. Instead of tracking calories, the amount of fructose consumed would be tracked.

Desired Components

In the following, the information gained from the interviews will be summarized and grouped into desired components for the app prototype. Table 4.4 visualizes which participants requested which components.

Desired Components	Participant ID
Information	P1, P2, P5, P8, P9, P11
Food List	P3, P6, P7, P8, P9, P12, P13
Dietary and Symptom Protocol	P4, P7, P8, P9, P11, P12, P13, P14
Recipes	P3, P4, P8, P9, P11, P12
Barcode Scanning	P3, P7, P13
Motivation	P1, P3, P5, P8, P11
Community	P1, P4, P5, P6, P9, P12
Essentials	P1, P7, P11, P12

Table 4.4: Overview of desired components requested from participants

Information Almost half of the interviewed persons (*P1, P2, P5, P8, P9, P11*) requested information about fructose hypersensitivity as an app component. The information should help to perceive what it means to suffer from fructose hypersensitivity and how to proceed after the diagnosis. It can be overwhelming to be unable to eat such many foods suddenly. For example, *P8* said that she had received no further information after her diagnosis and had felt left alone since she did not know how to proceed. Information

about foods with essential vitamins would also be precious for *P9*, as a healthy and balanced diet, especially with fructose hypersensitivity, is even more difficult. A graphical visualization of these facts would be beneficial for the person because the information would be easier to understand in that way, especially for younger affected persons.

Another important aspect requested by seven interviewees (*P1, P2, P4, P5, P6, P8, P14*) represented advice on the specific food intolerance. This advice should include, for example, suggestions on how foods can be tolerated better, how symptoms can be relieved, or what recipes can be cooked. *P8* thought that a list of 10 suggestions on better tolerating fructose would be beneficial. The participant *P1* also thought that an infographic or overview would be great to help explain the topic to people who are not familiar with fructose hypersensitivity.

Food List Seven participants (*P3, P6, P7, P8, P9, P12, P13*) suggested color-coded food lists as a valuable app component. When food items in the food list are clicked, detailed information about the product should be displayed. In this detailed view, information about the fructose and glucose balance would be very useful, especially for *P3*. *P9* and *P13* would also find the information about essential nutrients and vitamins a valuable feature. *P6* would generally prefer a point system instead of colors indicating the tolerance of a product. Furthermore, the interviewee would appreciate information on how to process a product best to make it even more tolerable for people with fructose hypersensitivity. Recipe suggestions would also be very helpful, including the selected product in the detailed view. The latter was also requested by *P8* and *P12*. For *P12*, it is also important to rate the own tolerance for the specific foods. This means it should be possible to enter whether foods are tolerated by oneself or not or whether they are only tolerated in certain quantities. In this context, *P7* thought it would be a good idea to provide an option to adjust the traffic light colors according to her/his own tolerance.

Dietary and Symptom Protocol The usefulness of a dietary and symptom protocol was highlighted by eight interviewees (*P4, P7, P8, P9, P11, P12, P13, P14*). Thereby a calendar format was desired by *P8* and *P12*. Furthermore, it should be possible to enter symptoms in addition to the meal entry and how the person felt during the day since stress can equally affect the tolerance of fructose. The latter was specifically noted by *P7*. *P4* would also appreciate an overview of the fructose amount of the products that were eaten during the day. For example, when meals are entered, the amount of fructose should be calculated based on the documented meal components. Furthermore, an overview of the nutrients and vitamins consumed would be extremely helpful for *P4*. Generally, entering the meals should be easy and fast. *P4* would like to enter the components of the meal in the shortest possible time since a lot of typing can be exhausting. Participant *P11* would also appreciate being able to write down her own experiences with the food intolerance. *P12, P13* and *14* brought up that reminders after a meal would represent a valuable component. These notifications should remind the user to write down what they consumed, how they felt after the meal and if any symptoms occurred. *P14* specifically commented that the app should provide the possibility to set the reminder individually,

as everyone's symptoms occur at different times after meals. This interviewee would find such reminders helpful, especially since one is regularly reminded to use the app. Without such reminders, the person would tend to stop keeping a diary at some point due to laziness. However, *P14* also noted that these reminders should have the option to be turned off, as some people do not like additional reminders. *P3* would not want to use another app that sends messages. She already gets annoyed with her drinking app, reminding her to drink enough water during the day. *P1* thought that statistics regarding symptoms or complaints would be helpful as well.

Recipes The interviewees *P3, P4, P8, P9, P11, P12* and *P13* would perceive recipes as extremely helpful since it is challenging to know what one may still cook and what not, especially at the beginning of the abstinence phase. *P12* would also appreciate if it were possible to grade the recipes according to how well they were tolerated. Furthermore, one should be able to organize the recipes, for example, in recipes that have already been tried out and in recipes one still wants to try. *P12* stated that he would like to create his own weekly cooking plan. Entering the ingredients of the food into a shopping list would facilitate grocery shopping. Moreover, the option to search for recipes would be a valuable component. *P12* also suggested providing a list of low-fructose snacks since many classic snacks contain a high amount of fructose. An apple, for example, is usually not tolerated when suffering from fructose hypersensitivity.

P12 thought that the possibility of creating a nutrition plan for a few days would be beneficial. It would also be convenient if not tolerated products were taken into account. In addition, being able to create a shopping list from selected recipes would support *P12*.

Barcode Scanning Three interviewees (*P3, P7, P13*) would appreciate the possibility to scan the barcode or ingredient list of food products. The app should indicate whether the product may be consumed or not after scanning. When scanning the ingredient list, problematic ingredients should be highlighted. *P13* said this would be extremely useful since fructose can be found under different names. *P7* stated that this would eliminate the need to read the ingredient lists of food products constantly.

Motivation Both *P8* and *P11* would like to see motivational elements in the app that help them stick with the restricted diet and not give up within a short period of time. *P11* said that the main challenge is to change the diet in the long term and not to fall into old habits. Therefore she believes that a point system would help the users to stay motivated during the therapy process. Moreover, the willingness to eat healthily should be strengthened. *P5* valued motivational messages, such as "The first week of the abstinence phase has already been completed!" or "This week you ate 40g less fructose!". *P3* mentioned that she did not want to receive messages from too many apps on her phone. If such a function existed, an option to turn it off should be integrated. *P1* would also find monthly balances motivating like, for example, that fewer symptoms occurred in the latest month or that some new recipes were tried out.

Community The interviewees *P1, P4, P5, P6, P9, P12* would appreciate a community function in an app for fructose hypersensitivity. It would be helpful to share ideas with other people affected. For example, recipes could be shared with others or own recipes could be uploaded. The latter *P12* would find especially helpful.

Essentials *P7, P11* and *P12* stated that it is important for the app to be customizable, as fructose hypersensitivity varies in severity for people affected and the tolerance of certain foods also varies from person to person. Moreover, the tolerance may depend on the current intestinal condition and stress level. The function to add notes to recipes regarding one's own tolerance or to modify recipes would therefore be necessary for *P11*. *P12* values the possibility of rating recipes. For *P7*, it would be important, as already mentioned, to have the option to adjust the traffic light colors according to the own tolerance.

P12 said that in general, it would be pleasant if the app did as much work for one as possible. For *P1*, the app should definitely be an all-in-one solution so that different apps do not have to be used to cover all functionalities needed.

Expert Opinion

In the opinion of *P11*, the biggest difficulty of patients suffering from fructose hypersensitivity lies within the long-term dietary change. As already mentioned, the dietary change should not simply be a brief change of habits, after which foods containing fructose are eaten again on a regular basis. A long-term dietary change is required for an efficient therapy of fructose hypersensitivity. The app should primarily strengthen the readiness for this step and support the process. Motivational aspects could help. The expert also stated that dietary change does not mean replacing every food product eaten with alternative products, such as sugar with rice syrup, which has a very low fructose content. A long-term healthy and balanced diet should rather be ensured, so one does not fall back into old habits. One of the problems the expert had experienced due to her own fructose hypersensitivity was the difficulty of knowing what to cook, especially after the diagnosis. That is why she wrote down her experiences and recipes she cooked during her abstinence phase in a book that is also available for purchase. An app that contains a collection of recipes would, therefore, be a great support for many patients, in her opinion. One aspect that the expert often emphasized includes the personal effects of fructose hypersensitivity. Affected people have different tolerances of certain foods and deviating symptoms. In her opinion, this is why it is crucial to provide the option to customize the app and/or to enter notes, comments, or ratings for recipes or foods.

Additional Remark *P1* mentioned that the food intolerance is generally challenging because one suffers from an impairment that is not visible from the outside. Therefore, for many people, this impairment does not exist. The interviewee also mentioned that she often uses the toilets for disabled people because with ordinary toilets organized in small cabins next to each other, one is confronted with an unpleasant situation when

the person is suffering from stomach problems. First of all, they are often occupied, especially the toilets for females, which can be problematic in case of diarrhea, which happens quite often when one eats not tolerated food. Secondly, using the toilet cabins is also very unpleasant since one can typically hear everything. *P2* and *P11* also said that it is not good to be constantly confronted with the subject. *P4* generally identified the issue that the topic of fructose hypersensitivity is not commonly known and that there is not much research conducted so far regarding this topic. The interviewee had found only one person in the German-speaking world on social media who is affected and is willing to talk about it.

4.4.4 Requirements

The subsequent step was to translate the obtained information through the interviews into requirements for the app. An detailed explanation of requirements was already described in section 2.4.1. For this purpose, the most substantial information noted by at least three of the interviewees will be summarized in the following.

One important matter during the interviews represented the desire for more information on fructose hypersensitivity. Most of the interviewees had conducted their own research on the topic to inform themselves on how to proceed after their diagnosis. Information, which summarizes the topic in a simple way and explains the next steps in treatment, would be a relief for many people. This should support individuals dealing with their intolerance and, most importantly, be a great time saver. Moreover, an explanation of the app components and their functions should be included.

Color-coded food lists were mentioned as a helpful tool by half of the interviewees. Some already use such lists from the internet or other apps concerning fructose hypersensitivity. These lists provide important guidance for the diet. As an extension of most conventional lists, the differentiation between the individual therapy phases was desired since the abstinence phase forbids some foods which are allowed in the long-term diet. Detailed information on fructose was also considered as a vital component, including information on the fructose content of the product per se and the glucose and fructose balance. Supplementing essential nutrients such as vitamins also represented an essential aspect that should be addressed since eating a balanced and healthy diet with fructose hypersensitivity was mentioned under the greatest difficulties. An overview of the nutrients consumed would provide support for this difficulty.

Advice in the form of suggestions for dealing with fructose hypersensitivity can be incredibly helpful when changing one's diet. These suggestions provide information on which aspects to pay particular attention to or how products can be better tolerated. This information can be very beneficial, especially at the beginning of the therapy process, when a lot of instructions are still unclear and unknown. As most interviewees stated, one's stress level can be crucial to tolerating fructose. Furthermore, it makes a difference whether fructose is eaten on an empty stomach or not, to mention two examples. Not having to figure this out on your own would be advantageous. A collection of recipes

could expand these suggestions to further facilitate the diet significantly. In addition, the possibility of sharing experiences with others was considered as further support representing an extension of available functions.

A dietary and symptom protocol function would be beneficial in order to have an overview of the diet and the resulting symptoms. Three interviewees already keep diaries for this reason. Additional functions could include providing statistics based on the entries in the diary, such as the number or frequency of symptoms in a month.

The function of scanning the barcode or ingredient list of food products in the supermarket was brought up by three interviewees. Such functions would facilitate the process of finding out whether or not a product can be eaten without concern.

Maintaining the motivation to follow the treatment process was also mentioned as a key aspect. Especially with this topic, this can be very challenging. It takes a lot of time until one knows by heart what can and cannot be eaten. Elements in the app that motivate the user to stick with the dietary change and eat a balanced diet would therefore be a significant help in the long term. In addition, the individuality of this specific food intolerance represented an essential aspect many interviewees addressed. The fructose hypersensitivity occurs differently in the symptoms or the individual tolerance of certain foods. It is, therefore, essential to be able to make personal adjustments in the app, for example, through the rating of food tolerance or by adding notes and comments to recipes.

The resulting requirements are formulated based on the guidance of [90] and can be seen in table 4.5. *Required* indicates whether the listed function contains core functions that interviewees requested and should therefore be included in the app. The table of requirements answers RQ01, which aimed to identify the requirements for an application using gamification elements intended to support people suffering from fructose hypersensitivity.

4.5 Phase 3: Mockup

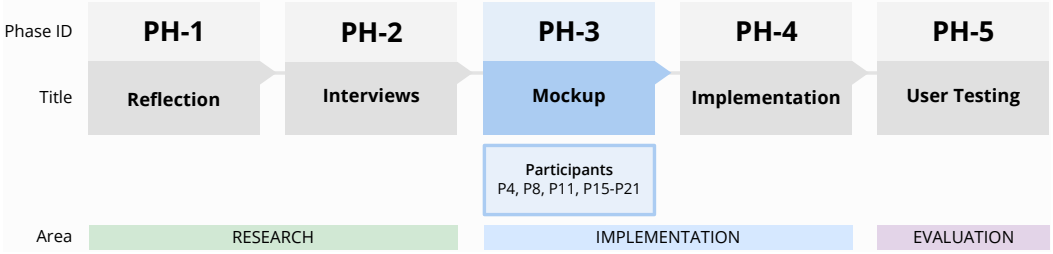


Figure 4.3: Phase PH-3: Mockup

Based on the requirements from the first phase, a prototype in the form of a mockup was created. The designing process was an iterative process according to the principle of UCD, which has already been described in section 2.5.1. In total 4 iterations were performed. Feedback was gathered after each version of the prototype and subsequently, improvements

to the design were made. If points of criticism and suggestions for improvement were not integrated, the reason for this will be explained in the corresponding iteration.

ID	Requirement	Description	Required
R01	Information	The application shall provide detailed information about fructose hypersensitivity, the process after diagnosis and how the app can support people suffering from fructose hypersensitivity	✓
R02	Food list	A food list with detailed information to each list entry, including the fructose amount, information about the foods tolerance in the different therapy phases and additional nutritional information should be displayed	✓
R03	Overview of fructose amount and essential nutrients	An overview of the most important nutrients in food products and in particular their fructose, as well as glucose amount, shall be indicated	✓
R04	Advice from people affected	Suggestions for eating certain foods containing fructose shall be provided	✓
R05	Recipes	Recipes shall be included in the application to facilitate cooking	✓
R06	Dietary and symptom protocol	The possibility to enter meals and symptoms in a calendar for a better overview shall be available	✓
R07	Barcode scanning	Detailed information about the tolerance of a scanned food product should be provided	✓
R08	Motivation (Gamification)	A gamification concept should be included to motivate users to stick with the restricted diet and use the app more often	✓
R09	Community function	The possibility to share experiences with other people suffering from fructose hypersensitivity should be available	✗
R10	Customization of components	The adjustment of app components shall be possible based on the own tolerance of food products and on the own severity of the food intolerance	✓

Table 4.5: Requirements gathered from the conducted interviews

4.5.1 Iteration 3a

After several brainstorming sessions, the first fundamental idea was manifested. Within the requirements analysis, 10 initial requirements were defined, which were transferred into 6 different features in the first version. Only the community function *R09* was not conceptualized, as this would represent an extension of the basic function. The function covering this requirement could be added to an extended version of the app prototype in future work.

When the app is launched by the user, a kitchen should be displayed on the home screen and a navigation bar at the bottom with five different icons should be visible, which can be seen in figure 4.4. These icons direct users to further functions: food list, recipes, dietary and symptom protocol, barcode scanning and information. The order of the functions mentioned corresponds to the order of the icons in the navigation bar.

Figure 4.4: Version 1: Bottom navigation bar

In the following, these five functions will be explained in more detail:

- **Food List**: The food list, containing a list of foods, can be viewed as a whole, containing all products, or categorized into sections such as fruits and vegetables. All foods are color-coded according to a traffic light system. The color indicates the assumed tolerance of the product. Detailed information on the food product will be displayed if one is selected. In this section, it is also possible to rate the product according to one's tolerance. Rating a food product will change the colored circle on the left side of the food list to a filled circle colored according to the rated color. This is done to already see in the food list if a product has been tested and rated. This should enable users to identify more quickly whether they can tolerate a product. It would be exhausting having to open the detailed view of every food to see one's own rating. Recipe ideas for the selected product are also displayed in the detailed view if available. Individual products can also be added to a list of favorites so frequently used foods can be looked up more quickly. This can be seen in figure 4.5. With this function, the requirements *R02, R03* and *R10* should be covered.
- **Recipes**: In feature recipes, different recipes can be read and tried out. All recipes should include cooking ideas containing only products with a small amount of fructose. The recipes can also be added to the recipe collections *Favoriten* or *Ausprobieren*. *Favoriten* should contain a list of favorite cooking recipes, *Ausprobieren* lists recipes that the user wants to test at some point. It should also be possible to create one's own cookbooks, i.e., collections of recipes out of favorite recipes. Recipes themselves should be editable in general. The option should exist to add

notes and information about individual intolerances of certain products. This concept can be seen in figure 4.6. This function should fulfill requirement *R05*.

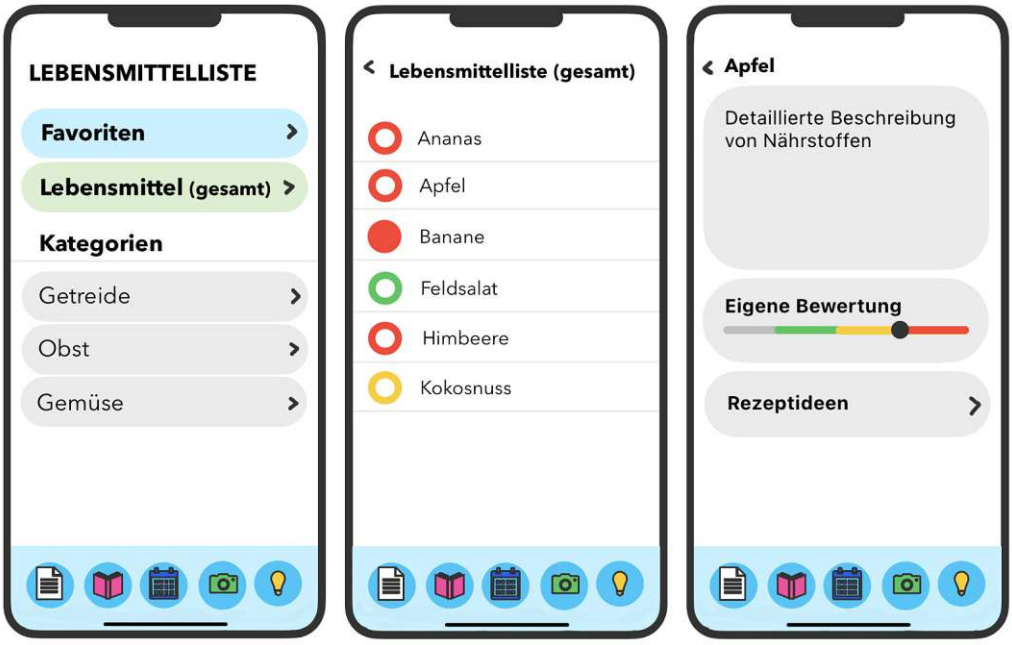


Figure 4.5: Version 1: Food list

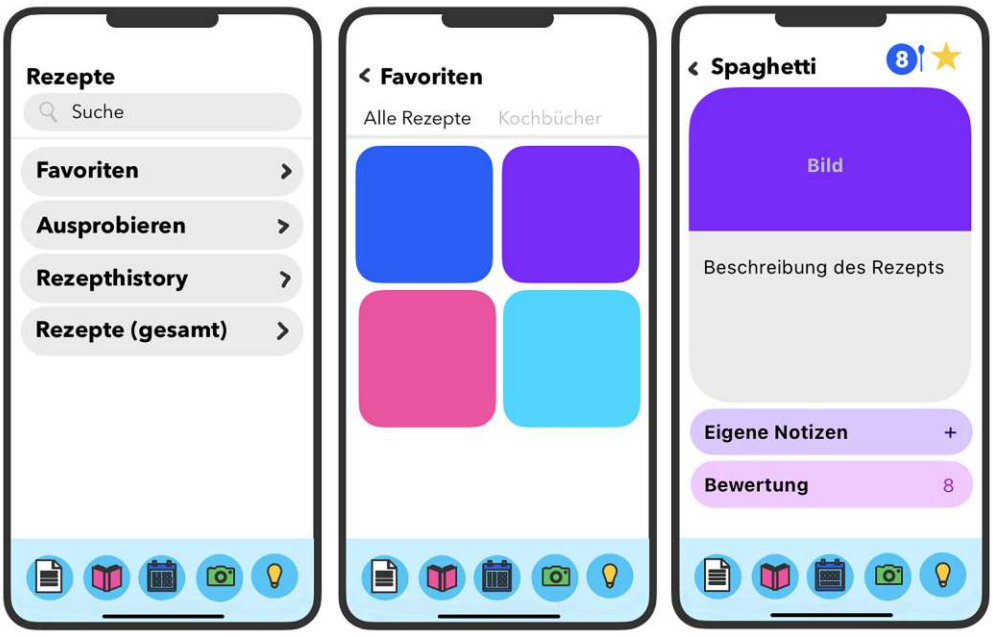


Figure 4.6: Version 1: Recipes

- **Dietary and Symptom Protocol**: This feature should offer the possibility to enter what one has eaten all day and which symptoms the person had after the meals or on the day itself into a calendar. If a meal is entered into the dietary protocol, the bowl for the current day is filled with a colored ball. If symptoms are entered or all fields are filled in, another ball is added. Three balls are the maximum amount the user can receive per day. This means everything that was possible has been entered into the protocol. This principle should give users an additional incentive to make diary entries. Furthermore, which days entries need to be included can also be seen visually. Underneath the bowls, the nutrients consumed should be displayed. This can be seen in figure 4.7. With this function, the requirements *R06* and also *R03* should be covered.

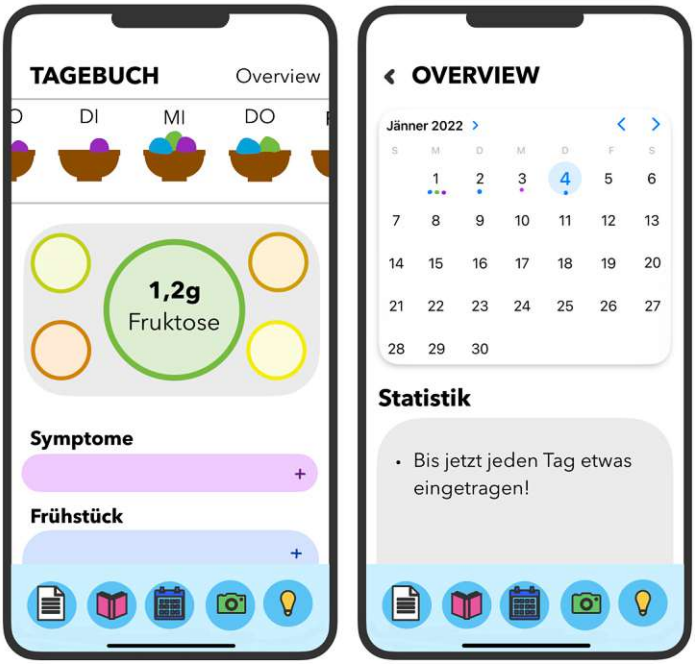


Figure 4.7: Version 1: Dietary and symptom protocol

- **Barcode Scanning**: When the barcode of a product is scanned, the app should indicate whether the product is tolerated or not. This should facilitate grocery shopping. This feature can be seen in 4.8 and will fulfill the function *R07*.

- **Information**: The information section should contain detailed information about fructose hypersensitivity, the process after diagnosis and how the app can help with this the food intolerance. Moreover, suggestions containing helpful advice should be listed. The feature can be seen in 4.8 and should fulfill the function *R01* and *R04*.

Figure 4.8: Version 1: Barcode scanning and information

A gamification concept was designed to support the users with the diet in a playful way. This concept should motivate the users to use the app more frequently. The user starts with an empty kitchen, which, as already mentioned, is displayed on the home screen. By completing different activities, such as trying out a certain number of recipes, the kitchen should be filled with various subjects, such as recipe books. Achievements should also be visualized in the form of refrigerator magnets. This will provide a visual indication of the user's progress. If the app is used during the different therapy phases, the progress is displayed as a progress bar based on the kitchen lighting. The more days that go by, the brighter the kitchen will be. At the end of the first phase, the kitchen is lit up completely and the progress bar is replaced with a modern lamp. The concept can be seen in figure 4.9 and 4.10. This concept should cover the requirement *R08*.

A initial consideration was to integrate a serious game into the app. However, through interviews with humans suffering from fructose hypersensitivity and the nutrition experts, multiple gamification elements distributed through the app were perceived as more suitable. By integrating the gamification elements in various functions, the app should be more fun and assist with the restricted diet.

Feedback

The described initial drafts were shown to four people (*P15-P18*) and feedback was gathered for improvement. The following summarizes the input received on each of the individual functions.

Figure 4.9: Version 1: Kitchen with a light source as progress bar

Figure 4.10: Version 1: Kitchen getting filled with items over time

Homescreen and Badges/Achievements The idea of the kitchen, which is filled when committing specific actions, was perceived as a good idea by all interviewees.

However, regarding the progress bar in the form of the kitchen lamp, *P18* mentioned some issues. First, she did not like it if users start in a "bad scenario", in this case, the dark kitchen. Secondly, she felt this could be depressing since dark is more associated with negative aspects. *P15* was not convinced by this progress bar either. Two concepts were proposed by *P18* as an alternative. The first idea was a calendar that hangs somewhere in the kitchen. Elapsed days would be displayed with a checkmark, indicating the progress made. The second idea was to display a baguette in the kitchen, which would get longer and longer over time. After completing the phases, people should receive the baguette in reality. This would require partnering with a bakery or other companies, but the users would receive something tangible and, in this case, also eatable. Instead of the baguette, another food product could equally be used. However, the idea behind it is to take a product that is well tolerated by individuals suffering from fructose hypersensitivity.

In general, a progress bar was considered an essential component of the app. *P15* thought it was important to see something happening. *P17* raised the general question of what happens when a user clicks on the kitchen or if no interaction possibility is intended. Furthermore, the question arose of how the users are informed that they have received an achievement. The interviewees also felt the lamp on the home screen was unnecessary. Instead of the lamp, the app name could be displayed as soon as the first therapy phase has been completed.

Food List *P15* would prefer icons in the shape of the respective food list item instead of a colored circle in front of the food product name. In addition, he missed an explanation of the color's meaning. For the interviewee, it was not clear that the colors indicate the compatibility of the particular food. *P18* also stated that she did not understand the meaning of the colors and especially the filling of the circles. *P17* suggested that if a user rates a product, the initial state should be visible somewhere. Otherwise, resetting the tolerance color back to its initial state would not be possible if it was changed unintentionally. Furthermore, the interviewee would find a burger menu on the food list screen beneficial. With this option, selecting a new category would be possible without returning to the overview.

Recipes Regarding the recipe overview, *P17* said that categories such as soups or breakfast were missing. Furthermore, the interviewee mentioned that the distinction between "Favoriten" and "Ausprobieren" was not needed. In the recipe's detailed view, whether the recipe has already been tried out could be indicated. If a recipe was marked as tried out, this could be shown visually with an icon or textually within the preview image of the recipe. *P16* perceived the name "Rezepthistory" as not suitable and would rename it to "Verlauf". Additionally, *P17* thought that there was, in general, no need for this menu item. When users try a recipe, they usually remember it. Furthermore, when adding the information that a recipe has already been tried out, the category "Ausprobieren" would be redundant. The recipe's rating can also be visible to the respondent directly in the image instead of being displayed in the top right corner of the detailed recipe view. *P18* suggested omitting the recipe overview page and displaying all

functions the same way the “Favoriten” is currently displayed. With a filter, switching between the different categories could be possible. The person generally wondered what the recipe looked like in the detail view if it was not rated or in the favorites.

Dietary and Symptom Protocol All respondents perceived the idea of the bowls that fill up when making entries as useful. However, *P16* would like to see a different bowl color and different ball colors. *P17* commented that the colors should generally be more uniform. Currently, many different colors were used for separate elements, which was partially confusing for the interviewee. Furthermore, *P17* said that she would prefer if users were given a ball for each entry, i.e., a separate ball for each meal. In the overview, the days could then also be colored according to the traffic light system, depending on the number of entries the users have made on a particular day. *P18* said that a day with symptoms should not receive more balls in the bowl than a day without symptoms. Therefore, she suggested that instead of writing an entry, there should also be an option to check off the entry field. If a meal was skipped or no symptoms were present on the day, the users should still be able to fill their bowl with the maximum number possible. Furthermore, *P18* was unsure what the different circle colors in the nutritional information indicated because a legend was missing. The overview was found to be very good by the interviewee.

Barcode Scanning and Information Both areas were found as valuable features by the interviewees. For *P16*, however, a question arose concerning the scanning function. He asked how the information as to whether a food is tolerated or not would be displayed after the scanning process - would an entry of the in-app food list be opened, or would a completely different visualization be displayed?

Additional Remark In general, *P18* noted that it was not indicated by the navigation bar which function is currently selected. *P17* also said that everything should be in the same language since English terms were used in some places. *P15* thought it would be a fun aspect to be able to read fun facts about fructose hypersensitivity in the app, which could also help those affected.

4.5.2 Iteration 3b

Based on the suggestions for improvement, the prototype was revised. The adjustments made in this iteration will be described in the following. In general, almost all suggestions were adopted.

Homescreen and Badges/Achievements One aspect the participants criticized was the lamp in the kitchen serving as a progress bar. Therefore, it was removed and replaced by a tear-off calendar on the kitchen wall. The remaining days of the abstinence phase should be individually definable in the settings menu, as the duration of this phase can be longer or shorter. Furthermore, the modern kitchen lamp, which should be displayed

after the end of the abstinence phase, was also removed. Since a question about the interaction possibilities with the kitchen itself came up during the feedback gathering, thoughts were given on this aspect. Subsequently, it was decided to include the option of clicking on received achievements. This action will direct the user to the overview of all achievements. Furthermore, post-its or notes will be placed on the refrigerator, which can be used to navigate to different areas in the app, such as the setting menu.

Food List The meaning of the colored circles in the food list was not clear to two of the interviewees. Therefore a question mark icon was added to the top right of the screen. Clicking on the icon should direct the user to a screen with a detailed explanation of the symbols and colors used. The circle shape itself was not changed and not replaced by icons of the food products due to concern that too many different icons would lead to confusion among the users. In the detailed view of the individual products, the rating method of one's own tolerance was adapted. The slider was replaced by colored smileys in red, yellow and green. Since it is only possible to choose between three different ratings, this type of rating was felt to be more suitable. In addition, a gray circle was added next to them. The rating will be set to its initial state when clicking on the gray circle. This was an aspect that the respondents also requested.

Recipes In the first version, it was noted that the overview screen with categories like "Favoriten" and "Ausprobieren" was not needed and could be replaced by a dropdown menu. This suggestion was implemented. All recipes are now displayed at once and can be filtered by eight categories using the drop-down menu. The possible filter options are: "Alle Rezepte", "Frühstück", "Mittagessen", "Abendessen", "Snacks", "Favoriten", "Ausprobiert" and "Rezeptbücher". Furthermore, an icon is displayed on the preview image of the recipes to indicate whether it has been added to "Favoriten" or has already been tried out.

Dietary and Symptom Protocol In the protocol, the colors of the bowls were adjusted and the concept of receiving balls for the bowls was adapted. The user receives a ball for each entry, such as entered symptoms or an entered meal. Furthermore, the possibility of checking off meals was included. If a meal was skipped, the meal can now be checked off. A full bowl can be achieved through this function, even if only some meals have a textual entry. A question mark was added to the screen to clarify ambiguities. Clicking on the question mark leads the user to a screen with information about the individual functions of the protocol. Adding this screen was especially important because the meaning of some components had been not clear to all participants.

Barcode Scanning and Information No changes were made in these two areas. Only a screen has been added to show the information displayed after scanning a product.

In general, the idea of displaying fun facts in the app was considered. However, after some consideration, no fun facts were found that fit the topic and could indeed support the user. The biggest changes of version 1 can be seen in the following figure 4.11.

Figure 4.11: Version 1: Changes

The reworked mockup was implemented in Adobe XD and designed for an iPhone 13.

A few changes were made during the implementation. The first step was to revise the bottom navigation. As *P18* noted, in the first mockup, it was not visible which menu item was selected. This was resolved in the second version. Furthermore, there was no possibility of getting back to the homescreen. Therefore, this was added and the icon leading to the information section was moved to the top right corner of the homescreen to have more space for the icons of the other functions in the navigation bar. In addition, icons for the achievement overview and one to reach the settings menu were added. The app colors were generally adapted to the iOS design. Furthermore, some explanations were included. An onboarding process was added to explain the functions. The process should be launched when opening the app for the first time. Furthermore, a question mark was included on the food list screen, which leads the user to a detailed explanation of the colors and symbols used. Additionally, a description of the individual functions of the dietary and symptom protocol was supplemented on the function's main screen. It can also be accessed by clicking on an added question mark.

The second version can be seen in the following images. Figure 4.12 shows an excerpt of the onboarding process, illustrating four of the contained screens: the welcome screen, a screen showing an overview of the included functions, the screen explaining the dietary and symptom protocol and the setup screen. The main functions of the app are illustrated in the figures 4.13 and 4.14. The first two images in figure 4.13 display the food list. The dietary and symptom protocol is represented by the second pair of images. In figure 4.14, the recipe function and the scanning of products is illustrated. The former is visualized in the first two screenshots and the latter function in the remaining ones. Figure 4.15 illustrates the gamification concept of the prototype. The kitchen with and without earned kitchen items, the message about winning an achievement and the achievement overview are displayed.

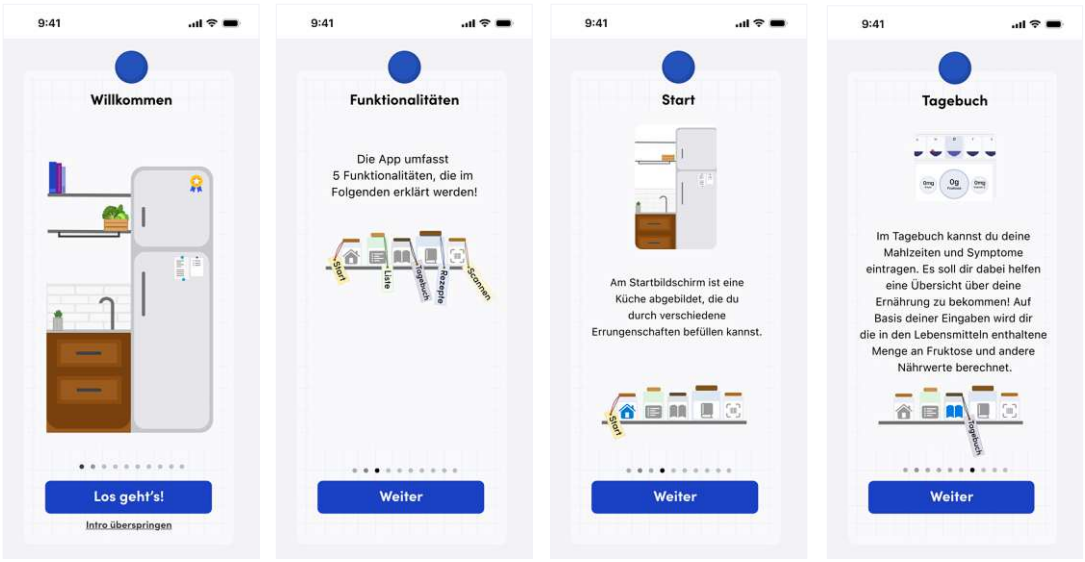


Figure 4.12: Version 2: Onboarding process

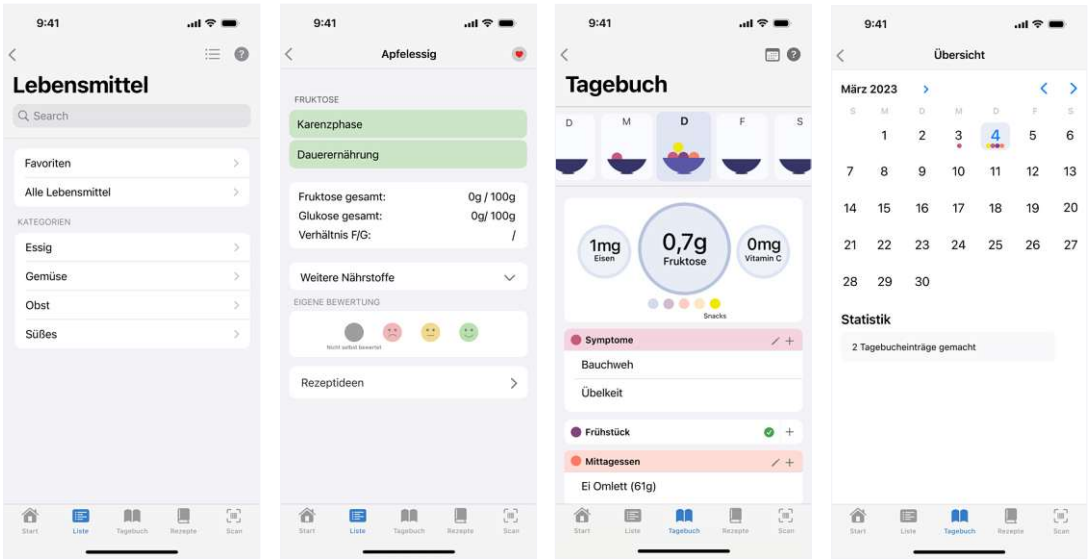


Figure 4.13: Version 2: Food list (left) and dietary and symptom protocol (right)

Feedback

The second version was shown to the same four people (*P15-P18*) as the first version of the prototype. In the following, the gathered feedback will be described.

All respondents generally perceived the prototype as well-implemented and easy to use. *P15* perceived the app as pleasantly structured and thought it was kept simple despite its numerous functions.

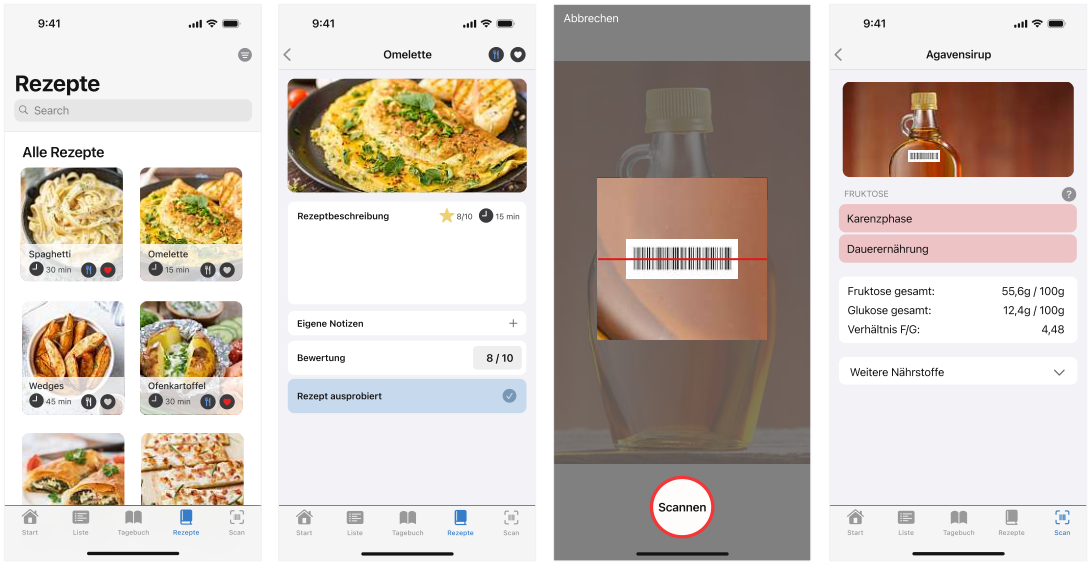


Figure 4.14: Version 2: Recipes (left) and barcode scanning (right)

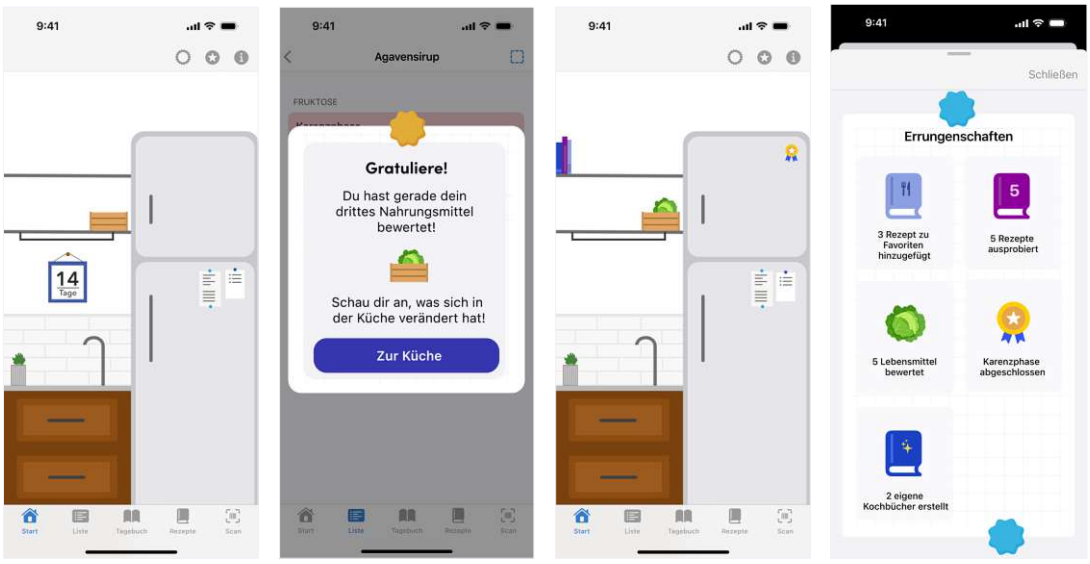


Figure 4.15: Version 2: Gamification concept

As general feedback, *P18* noted that the "back to the homescreen" arrows on the main pages of the individual functions (food list, dietary and symptom protocol, recipes) were confusing, as the user does not always access these functions directly from the homescreen. Moreover, *P17* stated that it would be nice if personal data, such as the name, had to be entered in the settings menu. She would also appreciate it if statistical data were displayed. An example would be the date of the app launch. Next to it, "Start deiner Ernährungsreise" could be displayed. These elements would give the app a personal touch.

Onboarding The onboarding process was perceived as a well-made introduction to the app since the prototype was explained in detail. *P16* stated that the onboarding process was helpful in learning how to navigate within the app. *P18*, however, wondered if the "skip intro" button was really necessary. Furthermore, the person suggested including a back button on each onboarding process screen and the possibility of reviewing the intro again later.

Homescreen and Badges/Achievements *P16* stated that the notes hanging on the fridge should be larger so that it is more evident that those can be clicked on.

Food List The colors of the phases (abstinence phase and long-term diet) caused confusion among two of the participants. *P17* thought it would be helpful if there was a question mark next to them. Clicking on the question mark should unveil detailed information about the different phases and the meaning of the colors. *P18* was especially confused by the stripe at the bottom of the colored boxes that include the name of the phases. An explanation of this would also be necessary for her. Furthermore, the person would appreciate it if the selected smiley was additionally outlined or highlighted. It was not clear to the interviewee which of the smileys was selected.

Recipes *P18* perceived the revision of the filter for the recipes as well done. In the last feedback round, the person expressed some criticism about this feature.

Barcode Scanning *P18* particularly liked the scan function. She found it very interesting that such a function was possible at all.

4.5.3 Iteration 3c

As with the previous iteration, changes and improvements were made after gathering feedback. The following section will describe the adjustments made after the second feedback iteration.

The "back to the start screen" arrows on the main pages of the individual functions (food list, dietary and symptom protocol, recipes) were deleted. Furthermore, some personal elements were added to the prototype. The user was then asked to enter her/his name during the onboarding process. The name will be displayed on a sign hanging on the kitchen wall later. Additionally, the date when the user launched the app will be displayed in the setting menu with the description "Start deiner Ernährungsreise" next to it.

Onboarding The possibility of returning to already-seen screens was added in the onboarding process. The option to skip the intro remained since if the app was already installed at some time the onboarding had already been viewed. The user might prefer to skip the introduction in this case.

Food List A question mark was added to the detailed view of the selected product above the names of the therapy phases. Clicking on it will open a detailed description of the phases and the used colors. Furthermore, the chosen smiley was clearly marked as selected.

The described changes can be seen in the following figure 4.16.

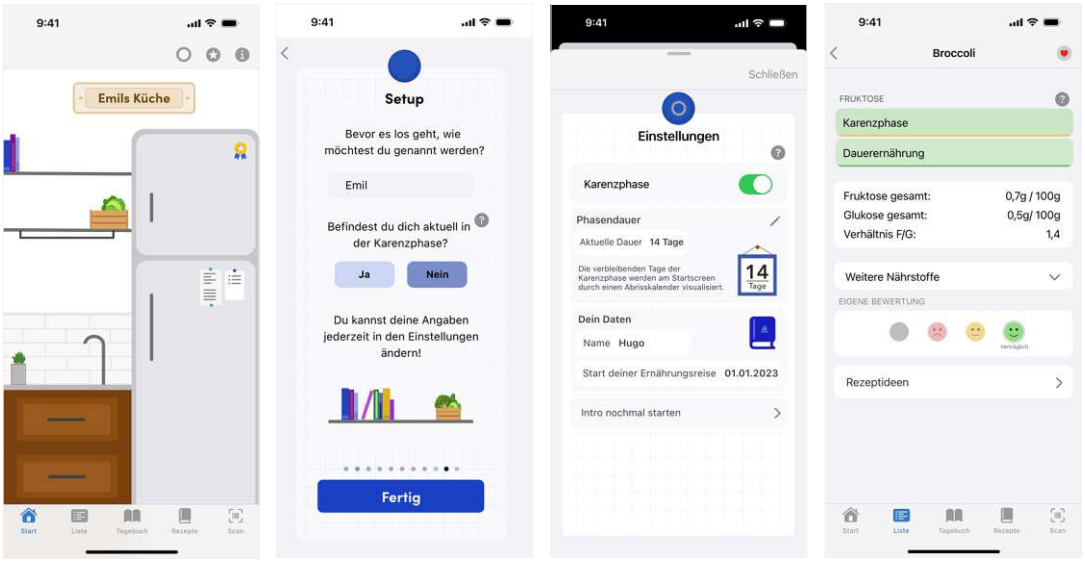


Figure 4.16: Version 2: Changes

Feedback

The revised prototype was shown to the two nutritional consultants (*P11* and *P21*) and four people (*P4, P8, P19, P20*) who suffer from fructose hypersensitivity. Some of them had already participated in the interview part. One of the nutritional consultants, *P21*, was met in person. All other participants provided their feedback in written form.

Feedback Affected People All four participants perceived the prototype to be very well implemented and that it provided a lot of positive feedback. Everyone would like to use the app on their smartphone and declared it would be extremely useful in everyday life. Especially the gamification elements and the kitchen caused a lot of enthusiasm. *P19* said these elements made the app more exciting and fun. *P20* perceived the app to be very well thought out. *P4* appreciated the high number of pictorial elements, especially in the kitchen. As a person who enjoys pictures, she valued this as very positive and motivating. The awards in the form of magnets on the refrigerator were also highlighted. *P4* perceived the app to be clear and not overcrowded. Furthermore, the participant stated that she had the impression of being able to design many components of the app individually and make adjustments according to her needs.

In general, the scanner and the dietary and symptom protocol received a lot of positive feedback. Viewing the amount of fructose eaten in the diary was considered very useful since it provides an overview of the amount consumed. Furthermore, the possibility to see the number of vitamins contained in products was highlighted by *P4* as an extremely useful feature. In combination with the scanner, this would be optimal for the participant.

As additional input, *P4* commented that it would be beneficial if the display of vitamins in the diary could be adjusted. This means providing the option to define the number of vitamins shown and to change the vitamins displayed in the dietary and symptom protocol themselves, from vitamin C to vitamin B12, for example. *P8* noted that it would be helpful to include the possibility of writing down more information in the diary, for example, which products had not been tolerated or what was suspected to be not tolerated. Currently, the symptoms and also the food entries could only be entered in the form of a list. A general note field with the possibility to write whole sentences would represent a valuable extension.

In the scanner function, it was suggested to extend the functions to the possibility of adding food products if a food did not exist in the database of the app's food list. The new food entry should subsequently be shared with others also using the app automatically. This function would increase the range of available foods for everyone.

Regarding the recipes' function, the visualization of the individual recipes was perceived to be very pleasing. Furthermore, the possibility of categorizing foods and the color coding of the products in the food list was particularly highlighted.

As a remark, *P4* suggested that the advice section should provide users with the opportunity to share their own experiences and advice with the community, which could be very helpful and motivating.

Feedback Nutritional Consultants The feedback gathered from the nutritionists *P11* and *P21* was very positive. Both stated that the app had the potential to support people suffering from fructose hypersensitivity to a great extent.

The experts especially highlighted the dietary and symptom protocol to be well implemented. *P21* stated that this feature had an enormous value for patients and dietologists. For patients they said, it provided an excellent overview of their diet and symptoms and dietologists received support in providing a diagnosis. Patients are often asked to keep a food diary when they suffer from dietary problems. Dietologists subsequently use this diary to find out which foods are not tolerated. For this purpose, patients are given sheets of paper with input fields to be filled in. This can be impractical, especially since they are frequently forgotten at home. An app with the stated function facilitates keeping a diary.

P21 brought up the idea of including an additional notes field where patients could write down comments that do not belong to the other entry fields. The field should offer the possibility of writing an entry as in a real diary. Compared to the other entry fields,

writing down whole sentences instead of bullet points should be possible. For example, when symptoms occurred could be written down, to what extent the symptoms occurred, or how long they lasted. More general information about the day could also be added. This also represented a feature requested by an affected participant. Furthermore, the possibility to enter meals should be as simple as possible, either through suggestions that can be clicked on or through entries linked to the recipe collection. If the creation of diary entries is tedious, users will not do it. The ability to save frequent meals or foods eaten would also be advantageous, making the diary entry easier.

In the food list function, the possibility to rate the food with smileys was perceived as well implemented. The display of the initial rating was equally found to be helpful. Regarding this function, it was specifically asked whether it was necessary to be able to rate the individual phases separately since this is not possible at the moment. *P21* said that no distinction needed to be made in this respect since the abstinence phase only lasts a short time.

In general, the app contains many specific nutritional information, both in the food list and in the dietary and symptom protocol. The question generally arose whether this was a good idea since negative aspects are also associated with it. While *P11* was also in favor of the exact indication of the fructose amount contained in the recipes, for example, *P21* was rather critical of this topic. *P21* stated that care had to taken so patients do not start to compulsively count all nutritional values. It can cause negative effects if a lot of food products are no longer consumed because a certain amount of nutritional value is exceeded. The expert said that in her studies, it was constantly said that counting nutritional values is not advisable. In general, the question is how many users are willing to weigh their food accurately to obtain exact information about their consumed nutritional values. If the display of the exact amount of nutritional values is included in the app, then there should definitely be the option to hide this information. However, the chosen examples of iron, vitamin C and folic acid are among the nutrients which are present only in a few foods. The selection of the nutritional values was, therefore, nevertheless perceived to be a good choice.

The recipe function was stated to be very well implemented. As already mentioned, *P11* commented that it would be useful to display the exact amount of fructose contained in the food to be cooked instead of just declaring the recipes contain a small amount of fructose. Furthermore, *P21* commented that it was important to include the possibility of adding own recipes.

Regarding the scanning possibility of products, the question arose if there were multiple use cases for this function since many products, such as fruit and vegetables, do not have a barcode that can be scanned. Moreover, the food cannot be scanned when eating in a restaurant either.

In the information section, *P21* commented that it would be advantageous if the advice list could be checked off. Since fructose hypersensitivity effects everyone differently, some suggestions may not help everyone. A checked suggestion would mean it works for the

person or improves their own tolerance. In addition, a supplementary note would be important that the given advice can provide relief but does not have to.

The integration of a community function was also discussed with *P21* since some interviewees stated that this function would represent a good idea. The expert countered that this function would not be very useful, particularly regarding the rating of food. Even if the majority of the community evaluates a food as tolerable, this does not have to be the case for oneself.

The gamification concept was perceived as very well implemented. Especially the idea of the bowls filling up with every made diary entry and the tear-off calendar received a lot of positive feedback. *P21* declared that the solution with the tear-off calendar was very well thought out since the length of the therapy phases depends on the person concerned. Therefore, the calendar and the possibility of setting the duration of the tear-off calendar individually represented a perfect solution.

As a final comment, *P21* suggested that the app could be repurposed for other food intolerances.

4.5.4 Iteration 3d

Only minor changes were implemented to the prototype after the last feedback round for the mockup. The possibility of hiding the display of the exact nutritional values in the dietary and symptom protocol and in the food list was included. The two adapted functions are displayed in figure 4.17. On the left image pair, the food list is displayed with and without the additional nutrition values. The right image pair visualizes the changes in the dietary and symptom protocol.

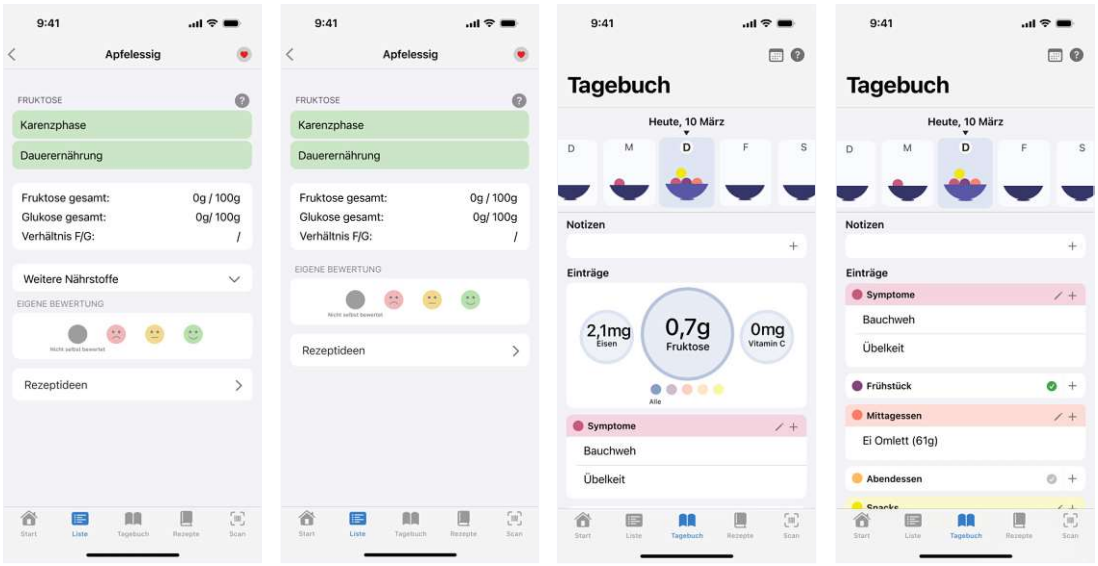


Figure 4.17: Version 3: Changes

4.6 Phase 4: Implementation

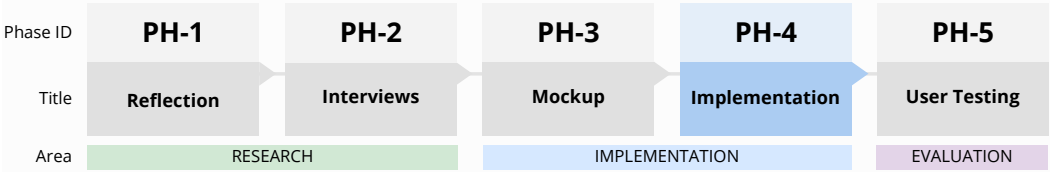


Figure 4.18: Phase PH-4: Implementation

Since the mockup implementation with all planned functions would go beyond the scope of the master's thesis, only the dietary and symptom protocol and the gamification concept were implemented. The protocol was chosen because it was mentioned as the most helpful function by the participants, the nutritionist and the dietologist. Furthermore, the dietary and symptom protocol represents a feature that does not exist within the applications analyzed in chapter 3. Since none of them combines a dietary and symptom protocol with gamification elements. In the following section, use cases, the technical implementation and the functions of the implemented app will be described in detail.

4.6.1 Implemented Use Cases

To give more insights into the interaction between the user and the system, the main use cases were described and visualized in use case diagram. The foundations were already described in section 2.6. A textual description of the use cases can be found in the appendix B. Figure 4.19 shows adding an entry to the notes, the symptoms, or the meal entry field. Furthermore, it illustrates the function to check off entry fields. With this option, it is possible to fill a bowl completely. The process of editing an entry in the dietary and symptom protocol can be seen in figure 4.20.

4.6.2 Technical Architecture

Since the app was conceptualized for an iPhone, the iOS software development kit (iOS SDK) was used for the implementation. The iOS SDK includes all the libraries needed to create an iOS app and contains an iOS simulator to test the developed app. The iOS SDK is included in Xcode, Apple's integrated development environment (IDE), which is used for the creation of iOS and Mac applications [91]. The iOS SDK provides four abstraction layers for the application to access the underlying hardware. The following figure 4.21 visualizes the abstraction layers of the iOS SDK. The core service layer gives access to essential features such as local data storage with Core Data and SQLite. Core Data is a framework for persisting complex data and offers all features of a multistore relational database [92]. The framework was used to store the users' diary entries and the acquired achievements. The data model is shown in figure 4.22a. Additionally, some variables were stored in UserDefaults. UserDefaults are used to store data between application launches and were created to store settings data [93]. In total, six variables with user-specific data are stored in the UserDefaults, which can be seen in 4.22b.

Git [94] was used as the version control system, together with Bitbucket [95] as the remote repository. The simulator integrated in Xcode and an iPhone 13 as a physical device were used for the app testing. Figure 4.23 visualizes the architecture of the implemented app prototype.

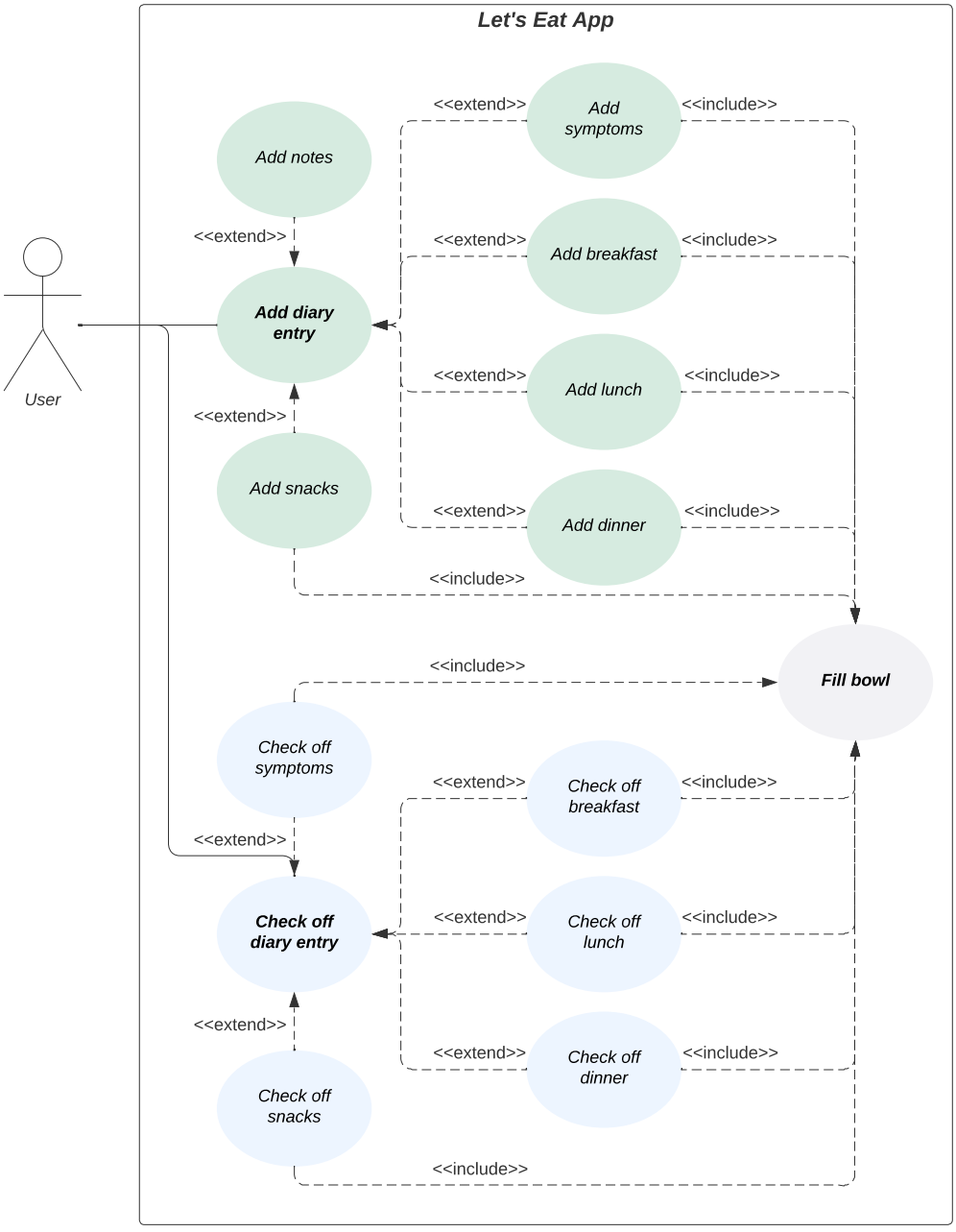


Figure 4.19: Use case diagram visualizing adding a diary entry

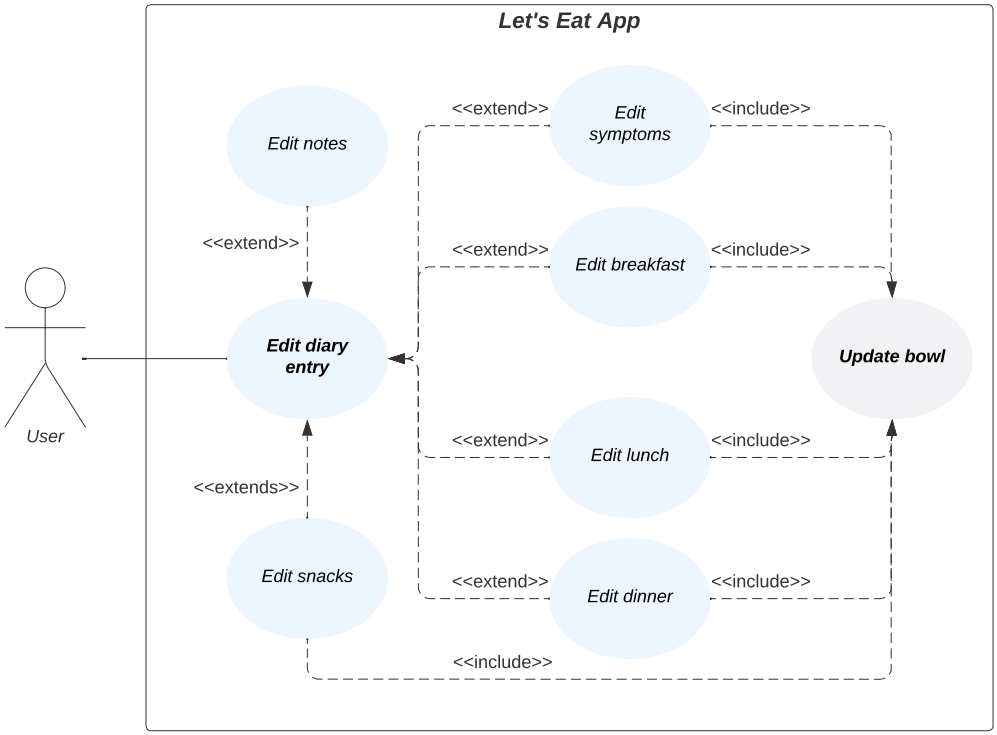


Figure 4.20: Use case diagram visualizing editing a diary entry

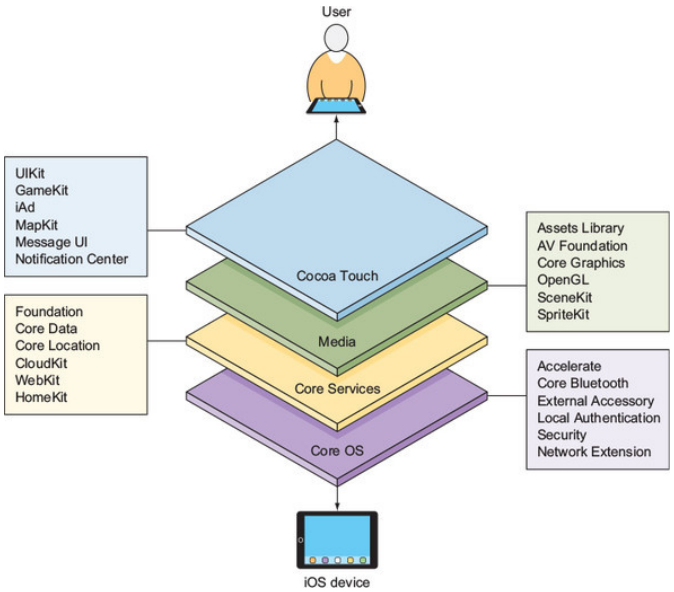
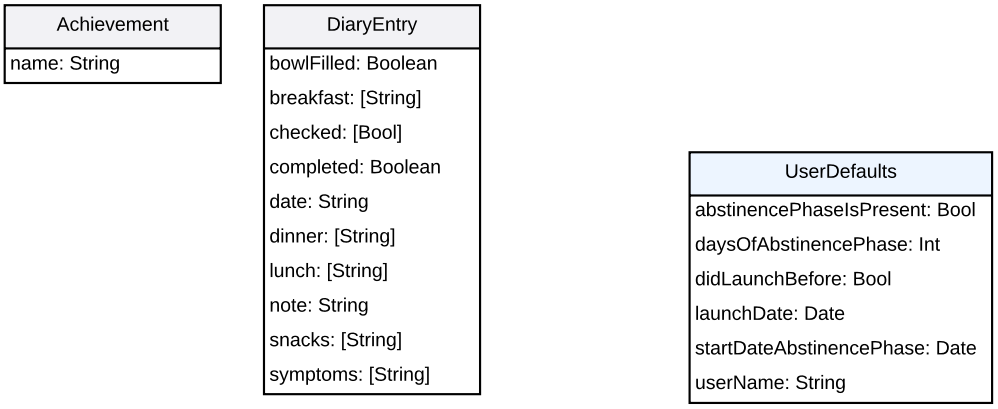


Figure 4.21: iOS SDK abstraction layers [92]



(a) Data model of the application (b) UserDefaults of the application

Figure 4.22: Data storage

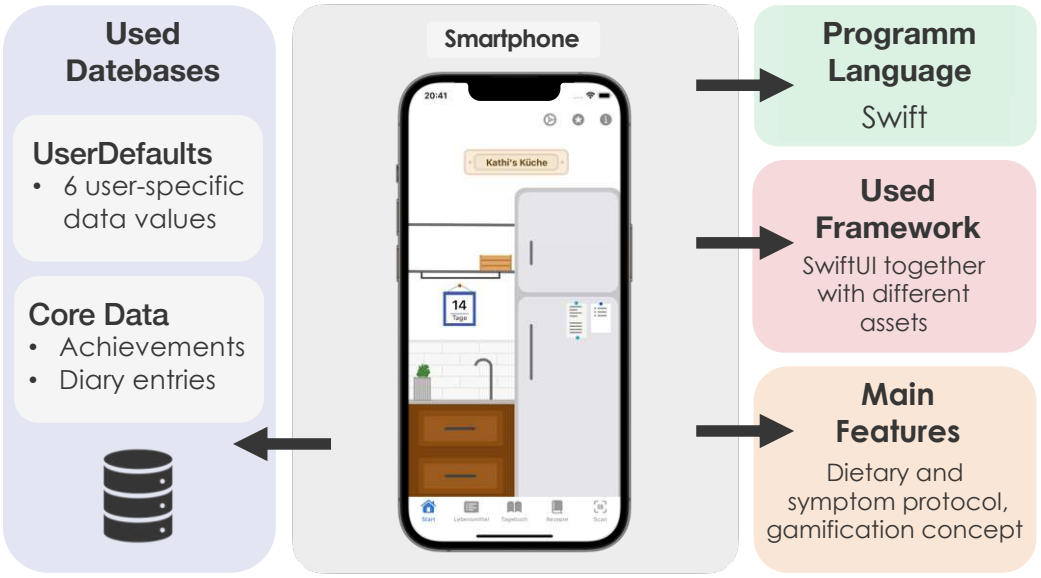


Figure 4.23: Architecture of the implemented application

4.6.3 Implemented Functions

During the implementation, care was taken to keep the application design as close to the mockup as possible. The app received the name “Let’s Eat”. This name was chosen since the app aims to support people suffering from fructose hypersensitivity by determining which foods are tolerated. A refrigerator was selected as an app icon based on the design of the kitchen in the application itself. The icon should indicate that this is an app about nutrition. The designed app icon can be seen in figure 4.24.

In the following, the implemented app functions will be described in detail.

Figure 4.24: App icon of the implemented application

Onboarding The onboarding was implemented almost in the same way as in the mockup. Since not all functions visualized in the mockup were implemented, the onboarding was shortened to the screens explaining only existing functions. Moreover, the last screen of the onboarding process in the mockup was removed and the containing information was included on the previous screen. The gamification concept as well as the dietary and symptom protocol are now explained within seven screens. On the last screen, users can enter their own name or a nickname and additionally indicate if they are currently in the abstinence phase or want to begin the phase. The entered name will subsequently be displayed on a sign hanging on the kitchen wall and, if the user has chosen the option "Yes" for the abstinence phase, a tear-off calendar will also be displayed on the kitchen wall. Parts of the onboarding process can be seen in figure 4.25.

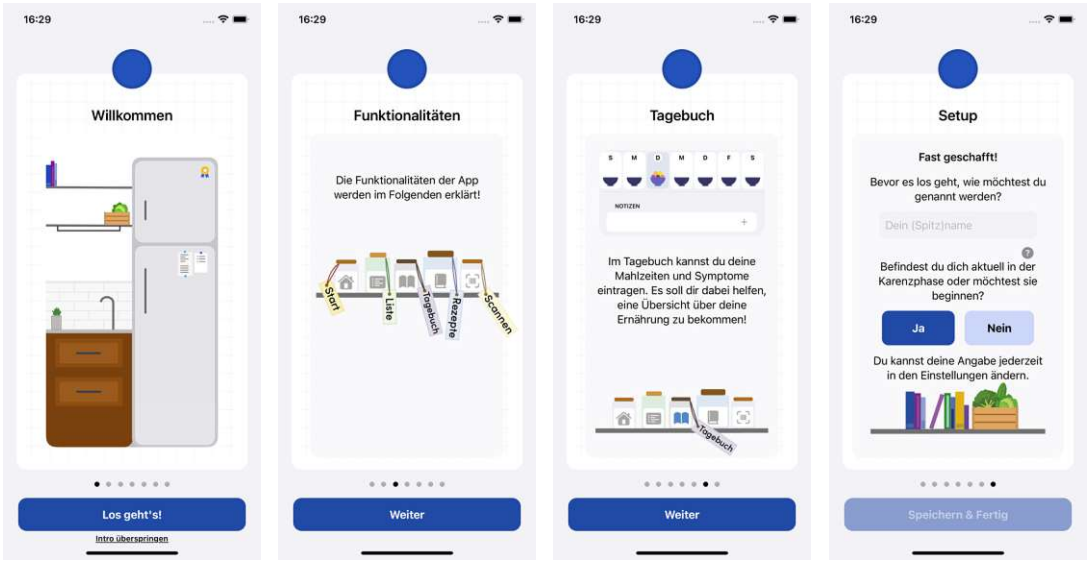


Figure 4.25: Excerpt of the implemented onboarding process

The name and the selection of the abstinence phase are saved by setting a variable in the UserDefaults. Additionally, two date variables are saved: *startDateAbstinencePhase*

and *launchDate*. The former, together with the variable *daysOfAbstinencePhase* will be used to calculate the days remaining until the end of the abstinence phase, which is used for the tear-off calendar. The latter is needed to display the start of the personal nutrition journey next to the username in the settings menu. The settings menu will be explained in more detail later in this section. The variable *didLaunchBefore* gets set when the onboarding process is finished. This is done so that the onboarding process will not be displayed again when the app is restarted. An overview of the UserDefaults could already be seen in figure 4.22b.

Homescreen The homescreen was implemented identical to the mockup. The name on the sign hanging on the kitchen wall depends on the user's input in the onboarding process. Moreover, the tear-off calendar is displayed if the user sets that she/he is currently in the abstinence phase or wants to start the phase. By clicking on the tear-off calendar it is possible to change the duration of the abstinence phase quickly, since the user will be automatically directed to the settings menu. With every acquired achievement, a new kitchen item is placed in the kitchen. The filling process is visible in figure 4.26. In the first image, the kitchen is empty. In comparison, on the last screen, some achievements have already been earned.

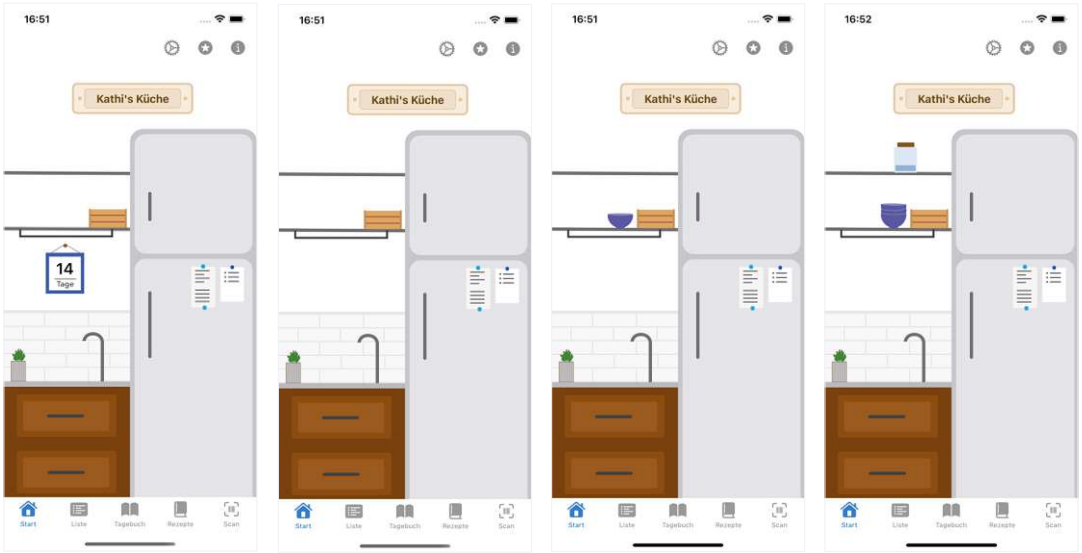


Figure 4.26: Implemented homescreen being filled with achievements from left to right

The progress made can be seen through the additional kitchen items. Navigating to the achievement overview page is possible by clicking on the star-icon in the top right corner or the left note on the fridge. The right note on the fridge directs the user to the settings menu, which can also be accessed through the gear-icon in the top right corner. The settings menu can be seen in figure 4.27. In the mockup, the option existed to navigate to the achievement overview also by clicking on the kitchen items themselves. During the implementation process, however, the idea arose to remove and replace this

function. If the user now clicks on certain elements in the kitchen, they will change their appearance. The changing of items is not limited to achieved kitchen items. Changing the appearance should enhance the user experience by giving the users the opportunity to modify the kitchen according to their preferences and to personalize it. With this option, every kitchen can look different. The changing of two items can be seen in figure 4.28. In this case, the blue jar on the shelf board has been switched to a dark blue one and the plant on the bottom left corner has been replaced by a vase with flowers. The i-con on the top right corner directs the user to the information sheet.

Setting Menu In the settings menu, it is possible to activate the abstinence phase and change the duration of the phase. Moreover, the name displayed on the sign hanging on the kitchen wall can be edited. Underneath the username, the date of the launch of the app is displayed. On the bottom of the screen the user has the option to view the onboarding process again. The menu can be seen in figure 4.27.

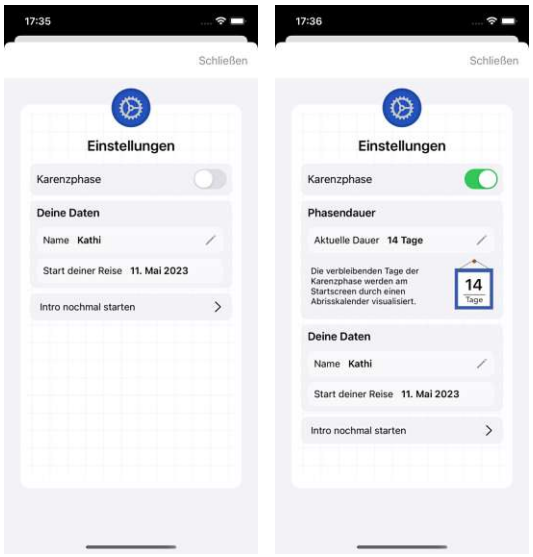


Figure 4.27: Implemented settings menu

Figure 4.28: Changed kitchen items

Achievements As already described, the achievement overview can be accessed through multiple options on the homescreen, for example, by clicking on the left note on the fridge. The design of the screen is equal to the design of the mockup. With every earned achievement, the progress bar increases until the total number of possible achievements is reached. In the prototype, it is currently possible to earn four achievements. A new achievement object will be saved in Core Data if the user gains an achievement. One of the achievements in the app can be earned by completing the first bowl. A bowl is completed when every meal and symptoms are filled with an entry or are checked off. The second one is earned by completely filling up five bowls. The third can be achieved when five different days have at least one entry and the last will be earned by

completing the abstinence phase. If the condition for winning an achievement is fulfilled, an alert is displayed. When clicking on the button “Küche anzeigen” the fully equipped kitchen is shown. Below the button, the different achievements are displayed with an explanation text underneath. The alert of winning an achievement, the filled kitchen and the achievement screen can be seen in figure 4.29.

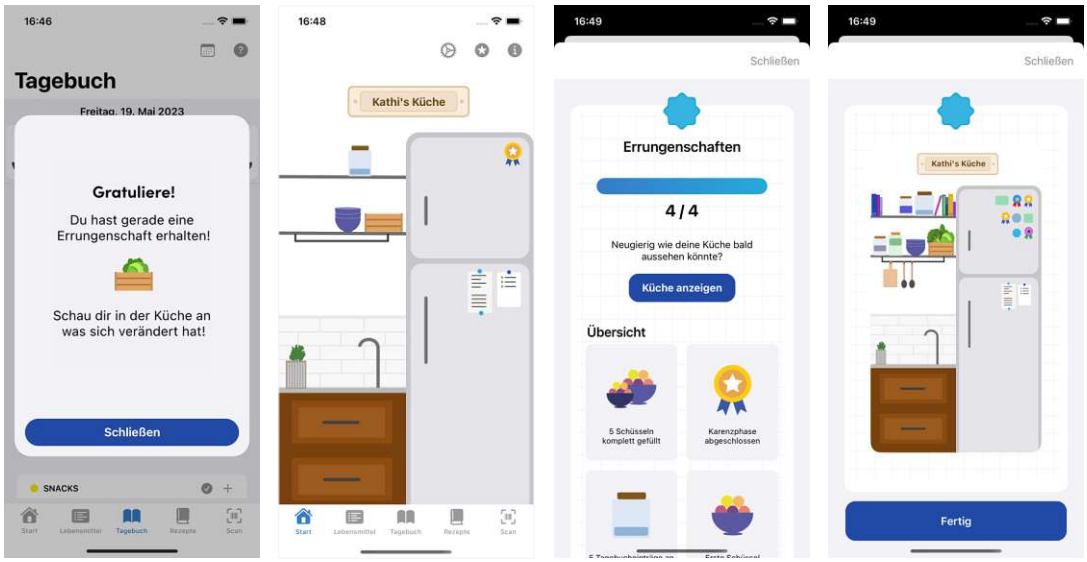


Figure 4.29: Implemented gamification concept

Dietary and Symptom Protocol The dietary and symptom protocol was implemented identical to the mockup. Due to the recommendation of the dietologist, it was decided to implement the version without the possibility of adding the exact number of grams of eaten food products first. The extended function could be implemented in a future version of the app. When opening the diary, the current day is automatically selected. For the saving of the diary entries, Core Data is used again. Each day has its own DiaryEntry object where all related information is stored. This could already be seen in figure 4.22a. If a diary entry is added or checked off, the bowl is automatically filled with a ball. If an entry is deleted or unchecked, the ball is removed again. The dietary and symptom protocol can be seen in figure 4.30. On the left screen, a day with no entries can be seen. With every new entry, the bowl of the selected day is filled with an additional ball. The selected day with the completely filled bowl is illustrated on the right image of figure 4.30.

In figure 4.31, the dietary and symptom protocol can be seen with multiple filled bowls. This is because diary entries were made on multiple days of the week. The bowls of Sunday and Monday are completely filled, because all meals and symptoms have been checked off and/or filled with an textual entry. Adding an entry is done by clicking on the “+” in each field (symptoms/meals). This opens a new sheet, as shown in figure 4.32. On this sheet, entries can be added, edited and deleted. When closing the sheet, the

bowl will update automatically. In figure 4.33, the implemented calendar overview can be seen. An external library named DateGrid [96] was used for this. Every day with at least one entry gets displayed with balls underneath the day according to the number of balls in the bowl. The current day is highlighted with a blue filling. At the bottom of the page, the statistics section is displayed.

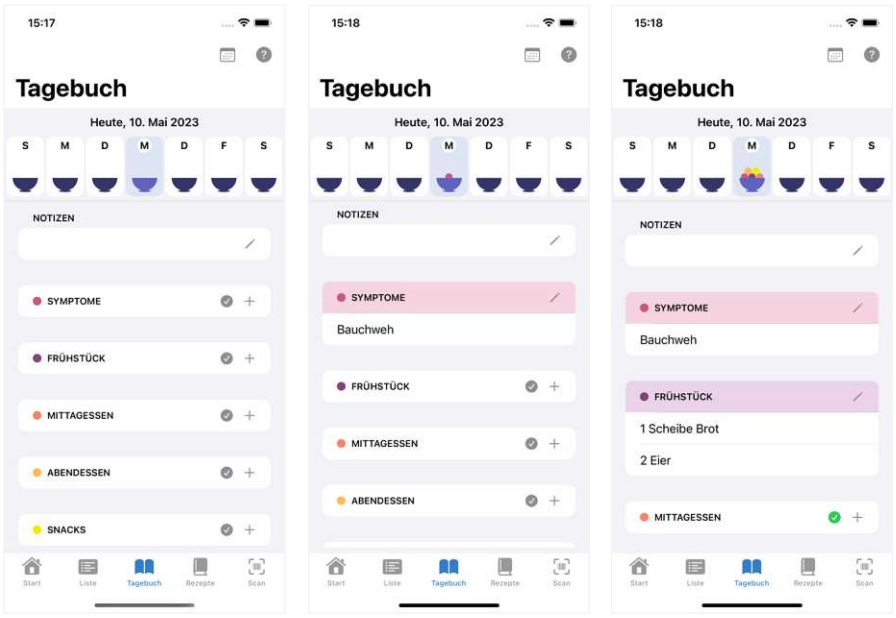


Figure 4.30: Implementation of the dietary and symptom protocol

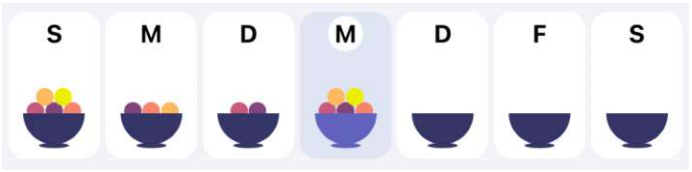


Figure 4.31: Dietary and symptom protocol with multiple filled bowls

Food List, Recipes and Barcode Scanning Since the food list, recipe and barcode scanning function were not implemented, a kitchen under construction is displayed when clicking on the tab bar icon in the bottom navigation. In future work, these functions could be implemented. In the middle of each screen, a maintenance symbol is displayed, serving as a button. By clicking on it, an image displays what the functions could look like in the future. This can be seen in figure 4.34.

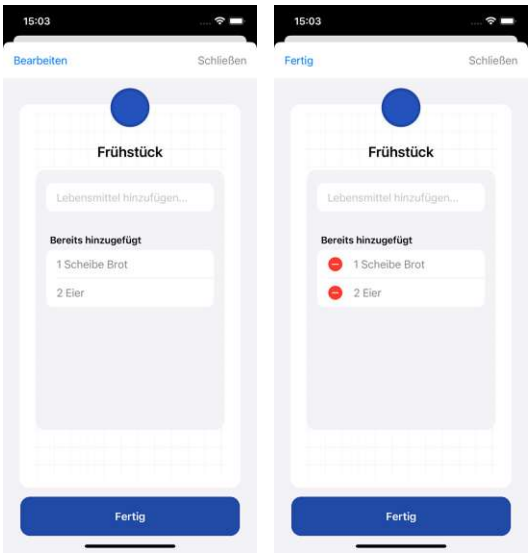


Figure 4.32: Adding and editing a diary entry

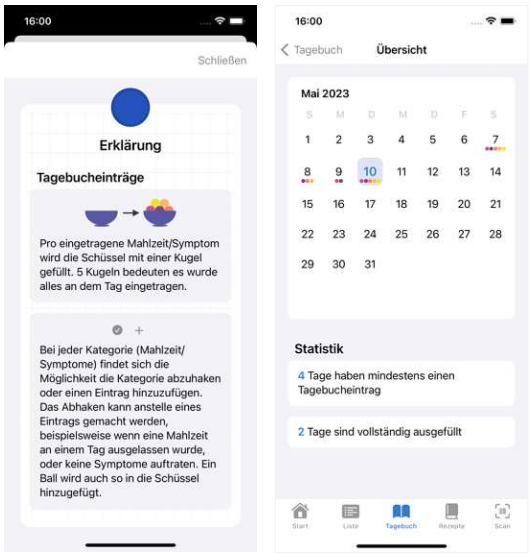


Figure 4.33: Information sheet and calendar overview

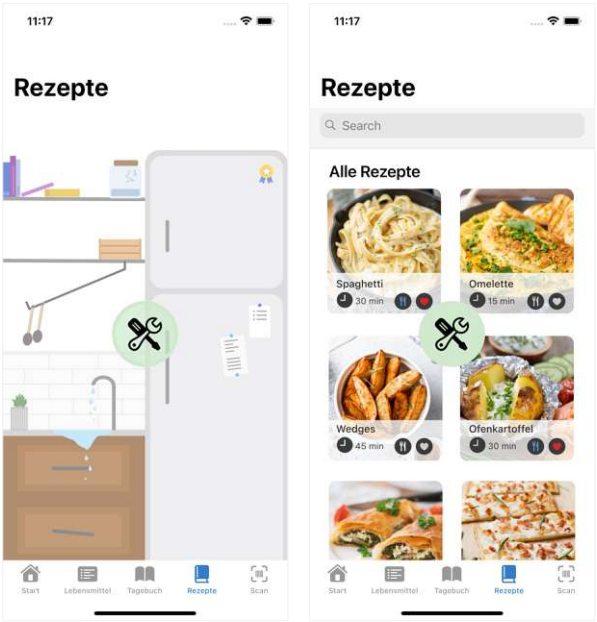


Figure 4.34: Implementation of recipe screen

4.7 Phase 5: User Testing

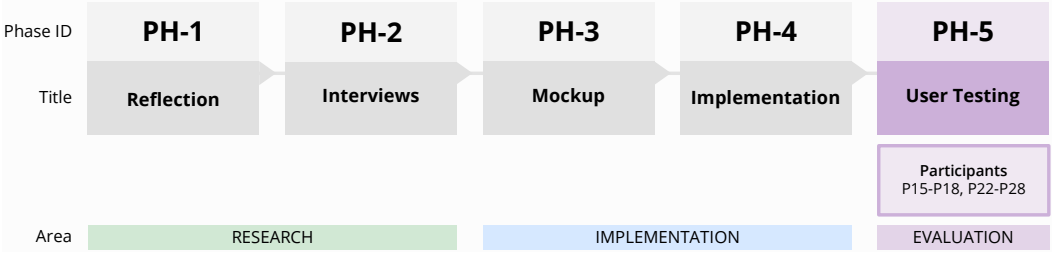


Figure 4.35: Phase PH-5: User Testing

The user testing was performed in two steps. At first, the "Thinking aloud" method was conducted with four participants. In addition, feedback was gathered for further improvement. In a second step, the implemented application was tested by seven participants to evaluate the usability. Lastly, the two affected individuals participating in this phase were interviewed regarding the usefulness of the app.

4.7.1 Thinking Aloud Protocol

For the first user testing, the "Thinking aloud" method described by Nielsen [97] was used. In this method, the participant is testing the system and simultaneously thinks out loud, saying everything that comes to his/her mind directly. Through this method, it is possible to receive detailed insight into the user's view of a system and issues can be identified directly. The recommended number of test users represents 3-5 [97].

Four participants (*P15-P18*) were asked to perform the "Thinking aloud" method. An overview of the participants was displayed in the table 4.2. All of them had already been involved in the iteration steps PH-3a and PH-3b of phase 3 described in section 4.5. Therefore, the concept of the app was already known. This method aimed to receive qualitative feedback. Existing difficulties were identified through this process to improve the application. In the following, the procedure will be explained in detail and the feedback received is discussed.

All four participants were met in person. Due to time constraints and participants' availability, conducting all four user tests at the same location was impossible. However, the procedure and the test setup were the same for every test run: the participant and the author sat beside each other at a table. This seating arrangement was chosen so that the author could observe the person performing the user testing. The app was built and run on an iPhone 13. As described in section 4.6.2, Xcode makes it possible to test developed apps on physical devices. Through this, it was possible to conduct the user tests with a smartphone and directly test the app on a mobile device instead of using a simulator on a computer. The app was reset to its initial state for every participant to have the same conditions for each run. Therefore each test run started with the onboarding process. Before the smartphone was handed over to each participant, a brief

explanation was given. Every participant was informed that they could not do anything wrong and that the method had the purpose of unveiling issues to be able to resolve them. Moreover, the participants were advised that some clickable elements lead to functions that are not working since they are only integrated via images and therefore have no actual functionality. A maintenance symbol is displayed in the middle of these screens, indicating the not implemented functions.

Afterward, the participants received the smartphone and started with the testing. As already described, every test run started with the onboarding process as the initial state. The users received the task to fill out all entries of two different days in the dietary and symptom protocol and they had to look at the month's overview. Moreover, the participants had to go to the achievement overview and view their received achievements. These tasks were given to test the main components, the dietary and symptom protocol and the achievement system since at least one achievement could be earned by completing the tasks. If the tasks were completed, the user testing was finished. Additionally, the participants were asked to click through the application and explore the other components. Notes were taken regarding what the participants said out loud and encountered difficulties noticed through observing them testing the app. Finally, the participants had the opportunity to give feedback or ask questions.

In general, all participants enjoyed using the app. The application design was perceived as well-made. The participant *P15* particularly had fun changing the appearance of the kitchen items and adapting them to his preference. Difficulties reported by the participants or observed by the author during the task completion are summarized in the following. Moreover, the received feedback will be described.

Onboarding During the onboarding process, *P17* noted that it was not clear that "Ja" had already been selected as an answer to the question regarding the abstinence phase. Moreover, if "Ja" was clicked, the user did not receive feedback since the button had already been selected and therefore, it did not change its color. This caused confusion. One suggestion was to replace the two buttons with a switch button or to deselect the button in advance. Moreover, *P18* clicked on the question mark and was confused about the sample text. She thought the appearing text was another button to get to the explanation about the abstinence phase. *P17* entered a very long name as her username. This caused the problem that the username was too long for the kitchen sign.

Homescreen *P17* stated that the notes directing to the achievement overview or the information screen were confusing since the actual menu icons for accessing these screens were right above them. The other participants, however, liked this feature. Moreover, the name of *P18* was displayed grammatically incorrect on the kitchen sign. This was due to the problem that every name received a "'s" as an ending, but this does not work with all names.

Dietary and Symptom Protocol Entering notes caused difficulties among the participants. For them, it was not clear how to leave the entry field and how to save an entry. Moreover, *P18* noted that selecting the current day was only possible when clicking on the top or bottom of the rectangle containing the weekday letter and the bowl. *P16* suggested changing the breakfast field's initial color purple with the symptoms field's color magenta to have the correct color gradient.

Additional Remark *P18* brought up the idea to display all achievements that can be received on the achievement overview sheet. The achievements earned should be displayed as they are and the other ones should be illustrated in gray. Moreover, she had the idea to add the possibility to define one's own goals that can be earned as an achievement.

Adaptions

Based on the issues described above, some changes were made to the app. All input text fields were revised, making entering and saving text input easier and more intuitive. In the onboarding process, the "Ja" and "Nein" buttons were adapted. No button is preselected anymore. Moreover, additional information will be displayed when clicking the question mark icon. The sign on the kitchen wall was adjusted as well. The length of the sign will now adapt based on the length of the username so that every name fits within the sign. The grammatical error was also corrected by displaying an apostrophe at the end of the exceptional names. The possibility of clicking on the notes hanging on the fridge remained. In the dietary and symptom protocol, the issue with selecting the rectangle containing the weekday letter and the bowl was fixed by making the whole rectangle clickable. Furthermore, during user testing, it was observed that participants first tried to click on the name of the meal in the dietary and symptom protocol before clicking on the plus icon to add an entry to the diary. To simplify adding a diary entry, the plus was switched with the checkmark icon and the whole button was made clickable. In addition, the color of the symptoms field was changed to the color of the breakfast field and the breakfast field received the color of the symptoms field. The achievement overview was not changed. However, the suggestions of *P18* could be implemented in future work.

With the final revision and completion of the app prototype, research question RQ02 is answered, which had the purpose of determining the design of a mobile application implemented to support the treatment of fructose hypersensitivity and the needed gamification elements. Screenflow diagrams of the implemented app can be seen in appendix C.

4.7.2 Usability Benchmarking

The final step was to test the prototype regarding usability and usefulness. To avoid distorting the results, only people who had not yet taken part in a phase so far were

involved in this step. Moreover, it was essential to include people suffering from fructose hypersensitivity since the app is intended to help people affected by this food intolerance. Seven people (*P22-P28*) were found who were willing to test the app and two of them were affected by fructose hypersensitivity. Details about the participants can be seen in the table 4.2. This procedure aimed to perform quantitative measurements using the system usability scale (SUS), which was already described in section 2.5.3.

The procedure was nearly the same as for the "Thinking aloud" method. All participants were met in person and in different locations, which was also due to time constraints and participants' availability. The testing setup and the equipment used were identical to the previous testing procedure.

After the explanation, the physical device was handed to the participants to perform the same tasks as during the "Thinking aloud" method with the implemented app. This time, however, the participants did not have to think out loud. The main focus was laid on usability testing and receiving a quantitative measurement. After the finished testing, a questionnaire had to be filled out. At first, demographic data on age, gender and the highest achieved school education had to be filled in. Moreover, the participants had to declare if they are suffering from fructose hypersensitivity. This was followed by the 10 system usability scale (SUS) statements. Regarding the SUS statements, the participants were informed that checking off all statements was essential. If they wanted to skip a question, they should put their cross in the center of the five-point scale since a rating is needed for each statement for the calculation. This procedure is also described by Lewis [45].

Initially, the intent was to use all 10 SUS statements from Brooke [42], which could already be seen in section 2.5.3. However, two changes had to be made after the first user testing. The first statement, "*I think that I would like to use this system frequently*" caused confusion since it only makes sense for affected persons in the context of the implemented app. People who do not suffer from food intake problems or do not want to change their diet do not have any use for such an app. Therefore the statement was adapted to "*I think that I would like to use this system frequently if I would suffer from food intake problems or want to eat more consciously*". Furthermore, the word cumbersome in statement 8 was not understood. Therefore, the word was changed to "*awkward*". This is also a modification described by Lewis [45]. The adapted statements can be seen in figure 4.36.

The values given for each of the statements and the overall results of all seven participants can be seen in table 4.6. Statement 1 received the most varied ratings. 4 participants strongly agreed in well imagining using the system, two checked off 4 and one person ticked 3 for the rating. Statements 4 and 6 were rated equally by all participants. All felt that there was no need for a technical person to support in using the system, nor that there was much inconsistency in the system. The calculation of the SUS scores revealed that all SUS scores are higher or equal to 87.5. The average SUS score is 92.14. Interpreting the SUS score using the acceptability scale out of section 2.5.3, the system can be seen as "acceptable".

			Strongly disagree				Strongly agree
	Statements		**1**	**2**	**3**	**4**	**5**
1	I think that I would like to use this system frequently if I would suffer from food intake problems or want to eat more consciously		○	○	○	○	○
2	I found the system unnecessarily complex		○	○	○	○	○
3	I thought the system was easy to use		○	○	○	○	○
4	I think that I would need the support of a technical person to be able to use this system		○	○	○	○	○
5	I found the various functions in this system were well integrated		○	○	○	○	○
6	I thought there was too much inconsistency in this system		○	○	○	○	○
7	I would imagine that most people would learn to use this system very quickly		○	○	○	○	○
8	I found the system very awkward to use		○	○	○	○	○
9	I felt very confident using the system		○	○	○	○	○
10	I needed to learn a lot of things before I could get going with this system		○	○	○	○	○

Figure 4.36: SUS statements on questionnaire

Statements	**P22**	**P23**	**P24**	**P25**	**P26**	**P27**	**P28**
1	5	5	4	5	4	5	3
2	2	2	1	1	2	1	1
3	5	5	5	5	5	4	5
4	1	1	1	1	1	1	1
5	5	4	4	5	4	5	5
6	1	1	1	1	1	1	1
7	4	5	4	4	4	4	4
8	1	1	1	1	1	1	2
9	4	5	5	4	4	4	5
10	1	1	1	2	1	1	1
SUS score	92.5	95.0	92.5	92.5	87.5	95.0	90.0

Table 4.6: Answers and calculated SUS scores of test persons

The two participants suffering from fructose hypersensitivity (*P23*, *P28*) were additionally interviewed after completing the questionnaire containing the SUS statements. The aim

was to elicit whether the application can provide support in the treatment of individuals suffering from fructose hypersensitivity and if affected people would use it.

Both *P23* and *P28* appreciated the app and said they would definitely use the implemented application if it were available in an app store. The design was perceived as very appealing in particular.

At the time of testing, *P23* had just started the abstinence phase since he received the diagnosis just one week before. He was, therefore, inexperienced about what he could eat. Consequently, he stated that the app could have supported him a lot, especially the recipes and the dietary and symptom protocol would have been beneficial and saved him a lot of time. At the time *P23* was interviewed, he had been using another app to write down his consumed meals, but he was not satisfied with its usability. Using the implemented app for this task would have been easier and much more fun for *P23*. Therefore, he could definitely imagine using the app, especially since he perceived it as very easy to use. The participant especially liked the concept of the bowls, as it supported and motivated him to write diary entries.

P28 was very excited about the gamification concept. She stated that this was an essential component of the app for her. Without this element, she would not use the app, as motivation plays a crucial role in her app usage. Two other aspects that were highlighted by *P28* represented the option of entering symptoms and the monthly overview. On the former, the participant especially appreciated the possibility of entering her own symptoms instead of choosing the symptoms from a predefined list. *P28* stated that she had had a case in an application where a symptom she had wanted to enter was not available and that no individual symptoms could be added. In general, the participant said that she also liked the aspect that the app was customizable to her own needs and preferences. She also found the idea of the other functions, which are currently only available as images, well thought of. *P28* especially liked the scan function. She also appreciated the information section in the app, which could have been very helpful at the beginning of her therapy.

The performed user testing answers research question RQ03, which aimed to determine how the usability of the provided solution is perceived by users.

CHAPTER 5

Discussion and Future Work

This chapter will summarize the most important aspects and findings of this thesis. Adverse food reactions will be described and carbohydrate metabolism disorder and fructose hypersensitivity will be explained. A particular focus will be laid on the treatment of fructose hypersensitivity. The reason for writing this thesis will be outlined. Subsequently, the research questions will be answered. Finally, an outlook on possible future work will be described.

5.1 Discussion

Adverse food reactions describe reactions or illnesses caused by the consumption of food. Specific nutrition components cannot be processed appropriately, causing symptoms in various body parts. Adverse food reactions are categorized into immune mediated and non-immune mediated forms of intolerance. The former is also called food allergies and the latter food intolerances. Their difference results in the body's reaction to the food ingredients. In the case of food allergies, there is a misdirected immune response and hypersensitivity of the immune system. Different mechanisms, such as enzyme or transporter deficiencies, cause food intolerances. As a result, a food intolerance is not life-threatening for affected individuals, but it can significantly reduce the quality of life, just as a food allergy does. Carbohydrate metabolism disorders represent the largest and most common group among food intolerances, causing impaired absorption of carbohydrates. Fructose hypersensitivity belongs to this category. In this case, the organism reacts to fructose, the so-called fruit sugar, which can be found in various amounts of foods such as fruits and vegetables. A three-step procedure is recommended as a therapy consisting of an elimination phase, a reintroduction phase and a long-term diet. Within the first two phases, numerous foods must be avoided completely or can only be eaten in small amounts. In general, the fructose level can vary widely in food products. Moreover, as the literature research has shown, food tolerance varies from person to

person and depends on various factors. In particular, it is influenced by how long the food remains in the stomach and the combination of different products consumed. Foods containing fructose are usually better tolerated when fat, protein, fiber or glucose are consumed simultaneously. In addition, a higher amount of glucose than fructose in a food product increases the tolerance. These aspects lead to a challenging treatment of fructose hypersensitivity. As a possible solution, an app prototype was developed to support individuals suffering from fructose hypersensitivity and to help with the difficulties arising from this food intolerance. Ultimately, the therapy process should be facilitated.

5.1.1 Research Question 1

> *What are the requirements for an application using gamification elements to support humans suffering from fructose hypersensitivity?*

Qualitative interviews were conducted to identify the requirements for an application using gamification elements. 14 people were interviewed in total. In selecting individuals for the interviews, the focus was laid on people aged 18-60 suffering from fructose hypersensitivity. The diagnosis must have been received at least two months before participating in the interview. This ensured that a certain fundamental knowledge about fructose hypersensitivity was given. One participant was interviewed as affected individual and nutritional consultant, since the person also works as a nutritional expert. A total of 10 requirements have been determined, of which 9 have been implemented into the mockup.

Information on fructose hypersensitivity presents an essential component desired from the interviewees, since most had to conduct their own research regarding this topic to inform themselves on how to proceed after their diagnosis. Therefore, the app shall provide detailed information about fructose hypersensitivity, the process after diagnosis and how it can support people suffering from fructose hypersensitivity.

Color-coded food lists were mentioned as a helpful tool by half of the interviewees. These lists provide essential guidance for the diet. As an extension of most conventional lists, the list should provide detailed information for each list entry, including the fructose and glucose amount, its tolerance in the different therapy phases and additional nutritional information. Displaying the essential components was especially highlighted, since eating a balanced and healthy diet was mentioned as one of the greatest difficulties when dealing with fructose hypersensitivity. An overview of the most important nutrients in food products should additionally be displayed.

Advice from people affected by fructose hypersensitivity was also identified as a required component of the app prototype. Instructions for dealing with fructose hypersensitivity can prove incredibly helpful when changing diet. Providing information on which aspects to pay particular attention to or how products can be better tolerated would bring great benefit, especially at the beginning of the therapy process, since in this phase a lot of instructions are still unclear and unknown.

As most interviewees stated, the tolerance of products can vary due to various factors like one's own stress level or whether fructose is eaten on an empty stomach. Not having to figure this out alone was seen as advantageous among participants. This is why a section full of advice from people affected should be implemented. Together with a recipe collection, cooking could be significantly facilitated. In addition, the possibility of sharing experiences with others was considered as helpful support.

The function of entering meals and symptoms into a calendar for a better overview was also requested by the participants. A dietary and symptom protocol is often done in the first therapy phase, which should provide an overview of the diet and symptoms. Integrating this feature should make this task more convenient.

Being able to scan the barcode or ingredient list of food products was determined as an essential function by the interviewees. It facilitates the process of finding out if a product can be eaten without concern. Furthermore, detailed information about the tolerance of a scanned food product should be provided.

Especially with fructose hypersensitivity, maintaining the motivation to follow the treatment process represents a major challenge. Therefore, a gamification concept that motivates the user to stick to the dietary change and eat a balanced diet should be implemented, since it would provide help in the long term.

The individuality of this specific food intolerance represents an essential aspect many interviewees addressed. Therefore it should be possible to adjust app components based on the own tolerance and the severity of the food intolerance. Personal adjustments within the app, like, for example, the option of rating the food with regard to one's own tolerance or adding notes and comments to recipes, should be possible.

5.1.2 Research Question 2

> *How could a mobile application be designed and which aspects of gamification could be integrated to support the treatment?*

Based on the gathered requirements, a prototype in the form of a mockup was created. The conceptualization represented an iterative process in which the design draft was revised and improved according to the principle of "user-centered design". In total, the process consisted of four iterations.

A unique feature of the developed app represents the conceptualization as an all-in-one solution. It is especially designed for people suffering from fructose hypersensitivity. The app concept includes four main functions: a food list, dietary and symptom protocol, recipes and barcode scanning. When the app is launched, a kitchen is displayed on the homescreen. By clicking on the i-icon, the users receives detailed information about fructose hypersensitivity and advice providing helpful suggestions from people affected. A notable feature of the implemented app obtains a high degree of customizability. Elements can be changed according to personal preferences and tolerance.

A gamification concept was designed to support the user with the restricted diet in a playful way. This concept should motivate the user to use the app more frequently. The app is launched by the user with an empty kitchen displayed on the homescreen. By completing different activities, such as trying out a certain number of recipes, the kitchen will be filled with various subjects, such as recipe books. Achievements are also visualized in the form of refrigerator magnets. This provides a visual indication of the user's progress. As a special feature, the possibility to adjust some kitchen elements in their appearance by clicking on them was added. If the app is used during the abstinence phase, a tear-off calendar is displayed hanging on the kitchen wall, indicating the day remaining until the phase is completed. Moreover, within the dietary and symptom protocol, bowls are filled by writing diary entries. With every entry made, the user earns a colored ball. If every field of a specific day has an entry, the bowl is filled completely.

The gamification elements used in the app include an achievement system and a progress status. Badges in the form of fridge magnets or kitchen items can be earned by performing different actions in the app. The user will be informed of winning an achievement through an information alert. The earned rewards can be seen in the kitchen and in the achievement overview. The progress status is included in form of a progress bar indicating how many badges have already been earned and how many are still to be achieved. Furthermore, the progress made can be seen visually based on the number of kitchen items.

5.1.3 Research Question 3

How is the usability of the implemented application perceived by users?

The application was tested and verified to determine the usability of the prototypical implementation. The user testing was performed in two steps. At first, the "Thinking aloud" method was executed with four participants and feedback was gathered for further improvement. The aim was to receive qualitative feedback. In the second step, usability benchmarking was conducted to obtain a quantitative measurement. Seven participants tested the app to evaluate the usability and usefulness of the implemented application. The system usability scale (SUS) score was used to make a statement about usability. The participants had to fill out a questionnaire with the 10 SUS statements.

The SUS score per participant was calculated and the average score was subsequently determined. All SUS scores from the seven participants are higher or equal to 87.5. The average SUS score is 92.14. Interpreting the SUS score using the acceptability scale, the implemented application can be seen as "acceptable". In conclusion, an application that can be easily used and is user-friendly has been developed in the course of this thesis.

5.2 Future Work

Even though the feedback from the participants was very positive and the evaluation delivered excellent results, existing app components could still be expanded and improved.

Functional Extension Since not all functions of the mockup were implemented, the food list, the recipe section and the barcode scanning could be integrated into future work. Moreover, the dietary and symptom protocol could be extended by displaying an overview of the daily nutrients and vitamins consumed. As one of the nutritional experts suggested, there should subsequently be the possibility to define whether additional nutrients and vitamins should be displayed within the food list and dietary and symptom protocol. In addition, the app could be expanded by implementing a community function. This function would enable users to share experiences, advice or recipes with other users. Moreover, with the possibility of adding additional products to the food list, users could expand the available database of food products. Furthermore, the reward system could be improved even further. During user testing, the idea of integrating the possibility of creating one's own challenges and goals that can be achieved arose. This could enhance the motivation of users even more.

Broader Evaluation Only two participants suffering from fructose hypersensitivity were interviewed during the evaluation. To receive more information about the usefulness of the implemented app, a further evaluation with more affected individuals would be valuable. Furthermore, the user testing was performed in a short amount of time. A test period of one week or a long-term evaluation would provide more insights into the user behavior and acceptance of the app. Through this, it would be possible to evaluate the impact of the gamification elements, for example, if the elements increase the motivation and usage of the application.

Target Group Expansion As one of the nutrition experts suggested, the app would also be suitable for other food intolerances like lactose intolerance. The app could therefore be extended to help people suffering from other food intolerances and thus support a broader target group.

APPENDIX A

Interview Guide

Einleitung

Begrüßung, Danke für Zeit und Erklärung von Ablauf

Einverständniserklärung

Gibt es noch Fragen zum Dokument oder dem Aufzeichnen?
Danke fürs Senden der Einverständniserklärung

Erhebung demografischer Daten

Alter:
Geschlecht:
Höchste abgeschlossene Bildungsstufe:

Fragen zur Frunktoseunverträglichkeit

Haben Sie eine vererbte Fruktoseintoleranz oder eine Fruktosemalabsorption?

Wenn Fruktosemalabsorption:

- Seit wann haben Sie eine Fruktoseunverträglichkeit bzw. wie lange wissen Sie schon davon?
- Woran haben Sie gemerkt, dass Sie Fruktose nicht vertragen?
- Wie sind Sie nach Ihrer Diagnose vorgegangen?

- Haben Sie sich selbst über die Fruktosemalabsorption informiert oder haben Sie eine Ernährungsberatungsstelle oder eine/n Ernährungsberater/in aufgesucht?
- Haben Sie die dreistufige Therapie (Karenzphase, Testphase, Langzeiternährung) durchlaufen?
- Wie hat sich Ihre Ernährung durch Ihre Fruktoseunverträglichkeit verändert?
- Was hat für Sie die größte Schwierigkeit bei der Ernährungsumstellung dargestellt?
- Bei einer Fruktoseunverträglichkeit muss auf viele Lebensmittel verzichtet werden bzw. können einige Nahrungsmittel nur in gewissen Mengen gegessen werden. Haben Sie irgendwelche „Tricks“, wie Sie trotzdem gewisse Lebensmittel mit Fruktose essen können?

Zusätzliche Fragen für die Ernährungsberaterin:

- Da Sie selbst auch Ernährungsberaterin sind, was sind Ihrer Meinung nach die größten Probleme vor denen Menschen mit einer Fruktoseunverträglichkeit stehen?
- Mit welchen Schwierigkeiten haben die Betroffenen gerade am Anfang zu kämpfen?
- Wo bedarf es Ihrer Meinung nach am meisten Unterstützung?
- Wie gehen Sie vor, wenn Menschen mit einer Fruktoseunverträglichkeit zu Ihnen kommen? Geben Sie Rezeptvorschläge oder Lebensmittellisten?

Fragen zu Apps für Fruktoseunverträglichkeit oder allgemein für die Ernährung

Beide Arten der Fruktoseunverträglichkeit:

Verwenden Sie eine App, die Sie bei der Ernährung mit Fruktoseunverträglichkeit unterstützt?

Wenn ja:

- Welche App verwenden Sie?
- Was gefällt Ihnen an der App bzw. welche Funktionen schätzen Sie am meisten?
- Was gefällt Ihnen an der App nicht bzw. welche Funktionen empfinden Sie als nur wenig hilfreich?

- Gibt es zusätzlichen Funktionen, die Sie sich in der App wünschen würden oder Bereiche, auf die in der App mehr eingegangen wird?

Wenn nein:

- Wieso verwenden Sie keine App, die Sie bei der Ernährung mit Fruktoseunverträglichkeit unterstützt?
- Was müsste eine App für Fruktoseunverträglichkeit Ihnen bieten, damit Sie sie verwenden würden?
- Welche Funktionen würden Sie sich bei solch einer App wünschen?
- In welchen Bereichen könnten Sie sich vorstellen, dass Ihnen eine App helfen könnte mit Ihrer Unverträglichkeit besser umzugehen?

Haben Sie schon einmal eine App für Nahrungsmittelunverträglichkeiten ausprobiert oder eine App, die bei der Ernährung unterstützten soll?

Wenn ja:

- Wie hieß diese App?
- Welche Funktionen haben Sie an dieser App besonders wertgeschätzt?
- Gab es Funktionen, die Ihnen nicht gefallen haben bzw. die Sie nicht hilfreich fanden?
- Hätten Sie sich zusätzliche Funktionen oder Bereiche gewünscht, auf die in der App mehr eingegangen wird?

Schluss

Haben Sie weitere Anmerkungen oder Ideen, die Sie noch gerne teilen würden?
Dürfte ich Sie zum Testen des App Prototypen nochmals kontaktieren?
Verabschiedung

APPENDIX B

Use Cases

Use Case UC01: Add a diary entry (notes)
Overview: The user wants to note own feelings and adds an entry in the dietary and symptom protocol.
Actor: User **Preconditions:** Application is installed **Trigger:** Change of emotional state
Basic flow: 1. User opens the application 2. User navigates to the *Dietary and Symptom Protocol* 3. User selects a day 4. User clicks on the plus "+" within the notes entry field 5. User writes an entry 6. User selects *Done* 7. The action is saved

Table B.1: Description of use case UC01

Use Case UC02: Add a diary entry (symptoms)
Overview: The user suffers from symptoms and creates a new entry within the dietary and symptom protocol.
Actor: User **Preconditions:** Application is installed **Trigger:** Symptoms occurred
Basic flow: 1. User opens the application 2. User navigates to the *Dietary and Symptom Protocol* 3. User selects a day 4. User clicks on the plus "+" within the symptoms entry field 5. User writes an entry 6. User selects *Done* 7. The action is saved 8. The bowl gets filled with a ball

Table B.2: Description of use case UC02

Use Case UC03: Add a diary entry (meal)
Overview: The user has eaten a meal or is about to eat a meal and adds a new diary entry to the dietary and symptom protocol.
Actor: User **Preconditions:** Application is installed **Trigger:** Food has been eaten
Basic flow: 1. User opens the application 2. User navigates to the *Dietary and Symptom Protocol* 3. User selects a day 4. User clicks on the plus "+" within an entry field (breakfast, lunch, dinner, snacks) 5. User writes an entry 6. User selects *Done* 7. The action is saved 8. The bowl gets filled with a ball

Table B.3: Description of use case UC03

Use Case UC04: Check off a food entry
Overview: The current day is nearly over and the user has not eaten a certain meal. To completely fill the bowl for this day, the user checks off the according entry field within the dietary and symptom protocol.
Actor: User **Preconditions:** Application is installed **Trigger:** A meal was left out
Basic flow: 1. User opens the application 2. User navigates to the *Dietary and Symptom Protocol* 3. User selects a day 4. User clicks on the checkmark "✓" within an entry field (breakfast, lunch, dinner, snacks) 5. The action is saved 6. The bowl gets filled with a ball

Table B.4: Description of use case UC04

Use Case UC05: Edit a diary entry
Overview: The user has forgotten to add an eaten food product and edits an existing diary entry to supplement the missing parts.
Actor: User **Preconditions:** Application is installed **Trigger:** Existing diary entry needs an adjustment
Basic flow: 1. User opens the application 2. User navigates to the *Dietary and Symptom Protocol* 3. User selects a day 4. User clicks on the pencil of an entry field (symptoms, breakfast, lunch, dinner, snacks) 5. User edits an entry 6. User selects *Done* 7. The action is saved 8. The bowl gets updated

Table B.5: Description of use case UC05

Use Case UC06: Display the month overview
Overview: The user looks at the statistics within the dietary and symptom protocol to gain an overview of the entries made in a specific month.
Actor: User **Preconditions:** Application is installed **Trigger:** User wants to receive statistical data of the entries made in a month
Basic flow: 1. User opens the application 2. User navigates to the *Dietary and Symptom Protocol* 3. User clicks on the calendar icon on the top right corner of the screen 4. The diary month overview is displayed 5. User can view the statistic at the bottom of the screen

Table B.6: Description of use case UC06

APPENDIX C

Screenflow Diagrams

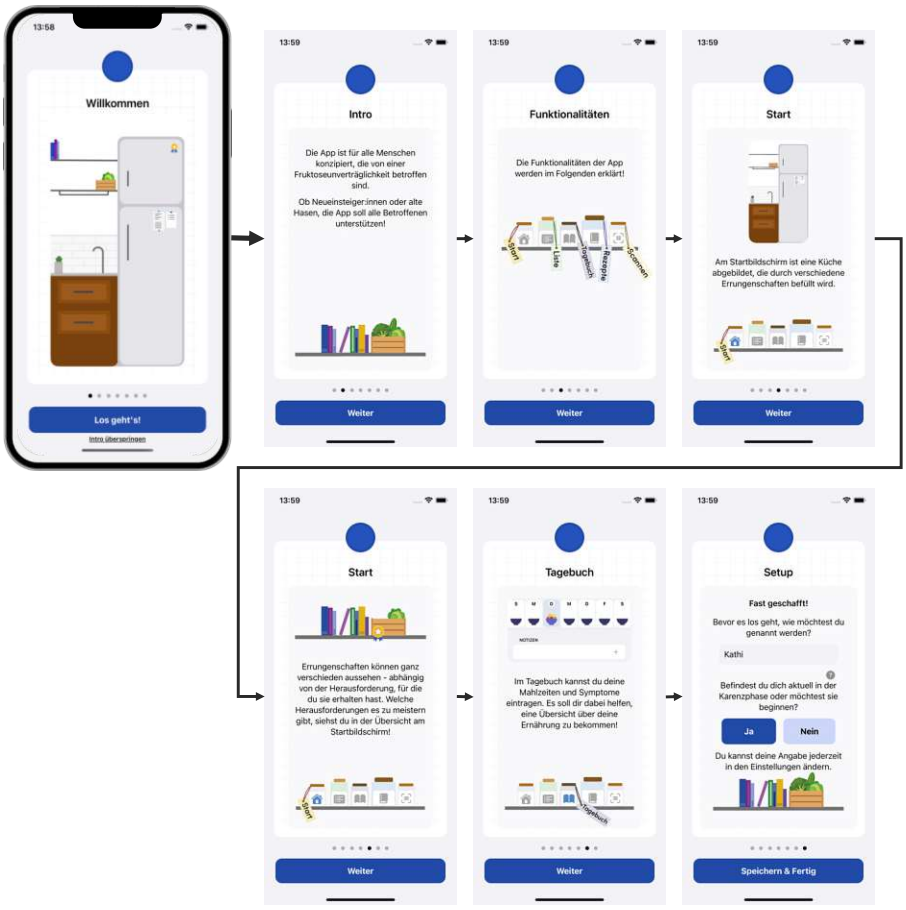


Figure C.1: Implemented onboarding process

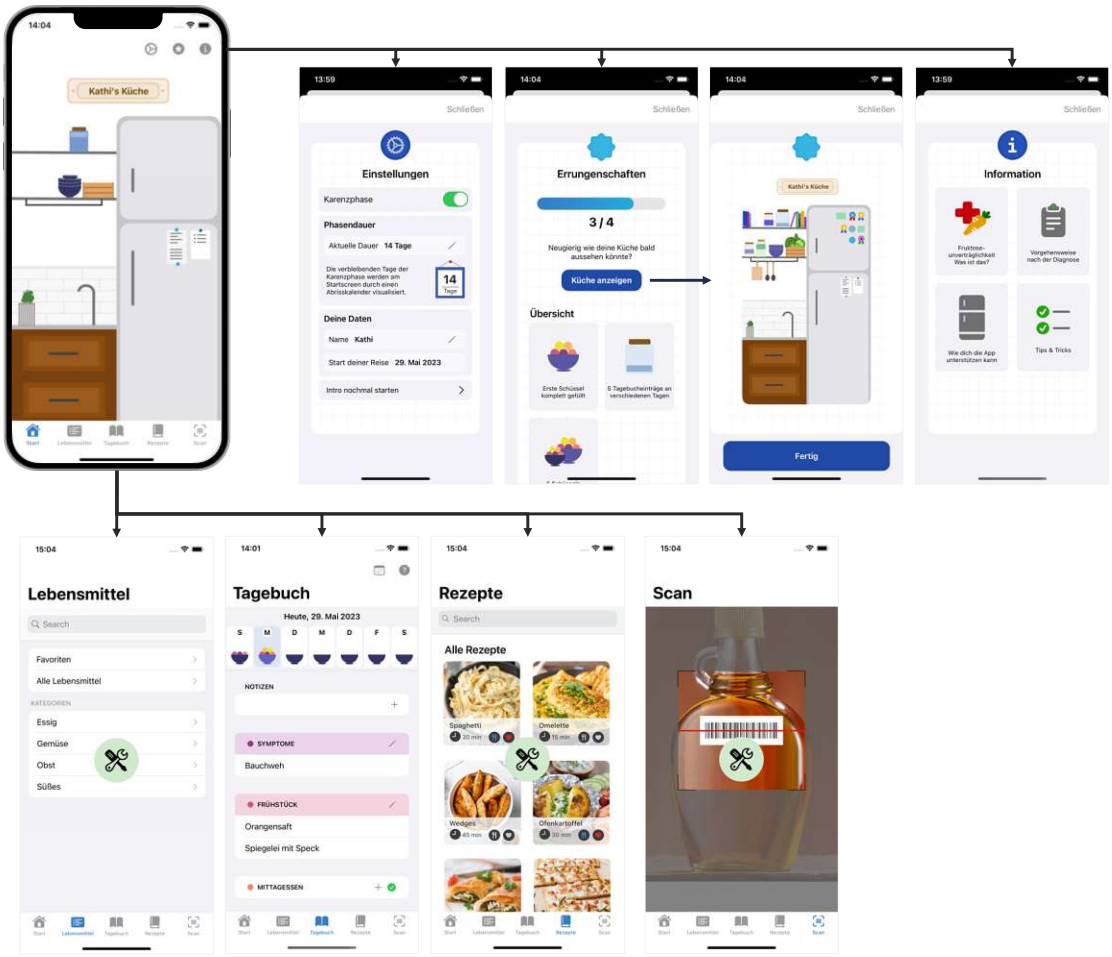


Figure C.2: Implemented homescreen with functions

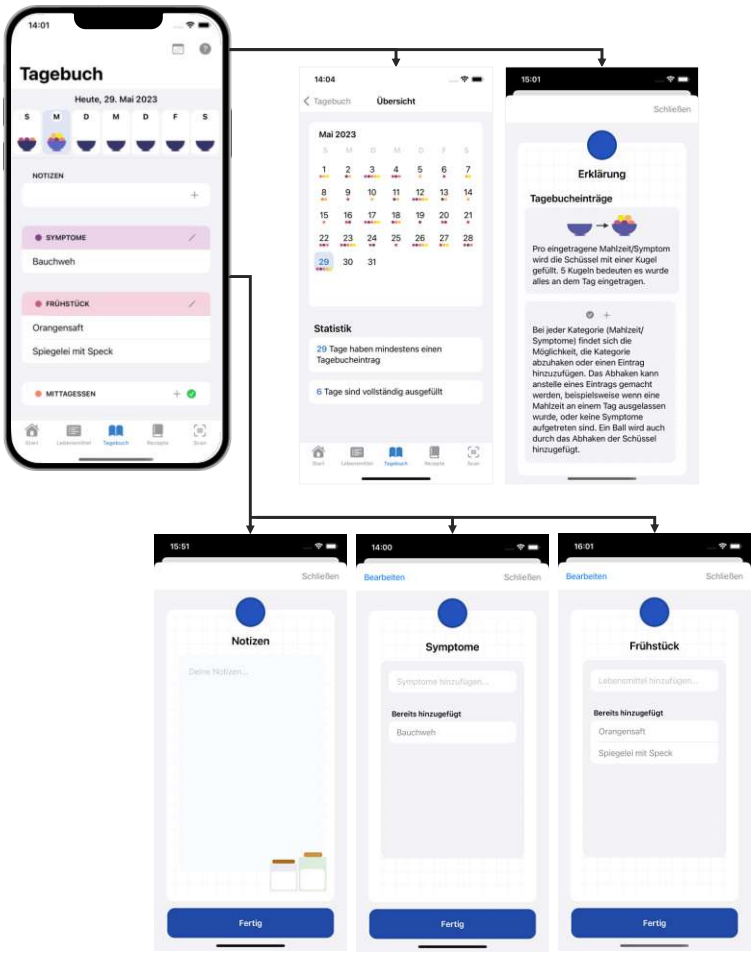


Figure C.3: Implemented dietary and symptom protocol

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