Improving nutritional intake of hospital patients using a persuasive tablet application

AALBORG UNIVERSITY
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Master's thesis

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Abstract

The main goal of this research is to improve the nutritional intake of hospital patients with a tablet application. Around 40% of patients in hospitals are malnourished, which leads to complications, increase in the length of stay and therefore additional costs. Current approaches for malnourishment in hospitals are investigated through a small literature study. Persuasion technology theories are discussed, which help in changing the behaviour of hospital patients regarding their nutritional intake. Insights from this are used in the design of an iPad application. This design is tested in a usability study, after which it is refined. The application is implemented and tested in a hospital in Denmark with eleven patients. Results from this user study show no significant change in nutritional intake for patients using the application. However, data from a questionnaire and interviews show that patients did find the application useful and it gave insight into their nutritional intake.

Preface

"Let food be thy medicine, and let medicine be thy food"

~ Hippocrates, ca. 400BC

It is common knowledge that eating and drinking well when being ill is important. However, when you think back to the last time you were ill, did you feel like eating or drinking? Sometimes we need a bit convincing for that.

In hospitals nutrition is an important aspect for a healthy recovery. However, it is also a problem with studies showing that more than 40% of the patients are under consuming. This leads to all kinds of complications, longer stays in the hospital and therefore additional costs.

This research project is an ambitious attempt to improve the nutritional intake of hospital patients with the use of a tablet application. This application uses persuasion theories from the sociology field to change the behaviour of the patient. It has been completely designed from the ground up, implemented and tested in the Aalborg hospital in Denmark.

As this report is my master thesis, it finalizes my MSc studies Human Media Interaction at the University of Twente in The Netherlands. Unusual about it is having supervisors from the University of Twente and Aalborg University in Denmark, which sometimes had its challenges. With Twente in general requesting more focus on theoretical research and Aalborg being more practical, this report tries to be somewhere in the middle. Many scientific theories are discussed – especially about nutrition and persuasion elements – while also an iPad application has been created and tested in the hospital.

Going to another country and live there for a while does have its challenges, but in general I consider it to be turned out really well. The things that I've learned, people I've met and experiences I've had were all amazing. I'm therefore truly grateful to the people that gave me this opportunity.

First of all, I would like to thank my supervisors, being Betsy van Dijk and Rieks op den Akker from The Netherlands and Jan Stage in Denmark. Especially in the beginning, the help of Jan Stage dealing with formalities and arranging a place to work and stay was marvellous, while along the way his feedback in the report was extremely helpful and I've learned a lot from that.

Although the original project did not come from the Aalborg hospital, people there were extremely helpful. I've had contact with people in the kitchen, nurses from different wards and of course patients. Every time I was truly amazed how willingly people were to help me with all different kinds of questions. In particular two people helped me a lot, which are Tina Beermann and Mette Holst. Tina's knowledge about nutrition as the head of dietitians in the hospital was really important for this research. Mette is the head of research of clinical nutrition and her experience with doing research in the hospital was invaluable. Without her help making contact with wards and finding patients, the user study would have been so much more difficult. But both also helped me with other

things as translations to Danish, offering me the possibility to have a place to work in the hospital, providing feedback on the application and so much more; I am really thankful for that.

All in all, the realization of this report has been an exceptional experience for me, from which I learned a lot. Going abroad for it was definitely worth it, and I can recommend everyone to do it. I wish the reader much pleasure in reading this thesis, as was for me the entire process towards this final result.

Sjoerd Smink
Aalborg, December 2012

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1 Introduction

1.1 Problem description

Hospital food is an important aspect of recovery in a hospital. Although hospital food doesn't need to be a star class cuisine, eating the wrong food or too few calories (malnutrition) doesn't help in getting better. In a study of 129 patients admitted to an intensive care, 43% were malnourished. Furthermore, the malnourished patients had more complications, stayed longer in the hospital and when looking at patients with a less severe degree of illness, "the existence of malnutrition led to a worse outcome than in sicker patients" (Giner, Laviano, Meguid, & Gleason, 1996). Other effects of undernourishment are: depression, fatigue, loss of will to recover, loss of muscle power, reduced cardiac function, risk of infection, and altogether lengthened stay in a hospital (McWhirter & Pennington, 1994). Another research even points out that the length of stay in a hospital is "progressively increased with the deterioration of nutritional status" (Messner, Stephens, Wheeler, & Hawes, 1991). Some patients die because of malnutrition; in 2007 reportedly 239 patients deceased because of malnutrition in English hospitals (Nutrition Action Plan Delivery Board, 2009).

That malnutrition is still a current problem, is shown in more recent studies. A comparison study of 1995 to 2002/2003 in Danish hospitals showed that little progression has been made in compliance with official Danish recommendations for institutional food service. This despite governmental attempts to improve nutritional problems (Mikkelsen, Beck, & Lassen, 2007). Even the Council of Europe pointed out that there are five common barriers in Europe regarding hospital food: "1) lack of clearly defined responsibilities; 2) lack of sufficient education; 3) lack of influence of the patients; 4) lack of co-operation among all staff groups; and 5) lack of involvement from the hospital management" (Beck, et al., 2001). This led to a resolution on food and nutritional care in hospitals, which was adopted by the committee of ministers of EU countries (Council of Europe, 2003).

The third barrier pointed out by Beck et al. (2001), the lack of influence of patients, is specifically dealt with in this research. Most European hospitals offer patients a choice between menus. However, it can be beneficial to advise patients choosing food, to e.g. prevent undernourished patients to choose the low-nutrition food option (McGlone, Dickerson, & Davies, 1995). Information about menus is sparse and inconsistent and sometimes a good description lacks. The report from the Council of Europe proposes guidelines that the provision of food should be individualized and flexible, with patients having the option of ordering additional food and informing patients about this. Patients should have some control over food selection, and feedback about likes and dislikes should be used to offer good nutrition (Beck, et al., 2001).

Some research has been looking into causes of malnutrition in hospitals. In a research of 1707 patients, it was seen that the food served in the hospital provided enough energy and proteins, however about 25% of the food was not consumed by the patients. 43% of the 1707 patients ate less than the minimum needs and up to 70% of the patients did not meet the recommended amount of nutrition (Dupertuis, Kossovsky, Kyle, Raguso, Genton, & Pichard, 2003).

Ironically, it appears that there is more than enough food served in hospitals, but a lot of it is returned to the kitchen. Food wastage is therefore also a problem in hospitals, as mentioned in a study that as much as 25-30% of the served food was thrown away (Almdal, Viggers, Beck, & Jensen, 2003). In the East of England alone, the BBC has calculated that 1 million pounds is lost on food wastage every year, which corresponds to a salary of 50 nurses. The percentages of food wastage per hospital differ extremely, from 3,5% as the most efficient to almost 15%. The main reason the inefficient hospitals gave for having more food wastage, was that they offered more choice in the menu for patients (BBC News, 2008).

1.2 Approach for improving nutritional intake

Improving nutritional intake is important for the health of hospital patients. There are roughly two ways to address this problem, namely to focus on one of the two distinct parties involved: the hospital with its staff or the patients. When this research would focus on the hospital, it would almost certainly require organizational changes. Offering more dinner options for the patients or introducing personalized menus seems a good solution and will probably increase patient's satisfaction with the food, but is in practice not possible for a large hospital. Another option is to bring changes to the education and instructions of nurses regarding nutrition, which can have a positive effect on the nutrition of patients (Lassen, Kruse, Bjerrum, Jensen, & Hermansen, 2004). Nevertheless, changing routines and work methods of hospital staff is challenging (the results of the given example were dubious) and given the short timespan of this research almost impossible. This research will therefore not focus on how changes made to the hospital can improve nutritional intake, but takes the current situation in the hospital as premise and instead focuses on the patient.

The first step is to investigate the reasons why patients aren't eating or drinking enough. Sick people lose their appetite, but there can be more reasons for not having a balanced metabolism. Reasons that can be thought of are patients that undergo surgery missing a meal, having religious reasons not to eat certain food or maybe that the food is served too cold or too hot.

Secondly, it can be assumed that a large factor responsible for the patient's nutritional intake, is the patient himself. It must be possible to persuade the patient (up to a certain limit) to consume the correct nutrition. This correctness can be to eat more in general, but some patients maybe have to eat more of specific kinds of food, increase their vitamin intake, or simply drink more. Besides that, patients can have preferences for certain kind of foods. All this has to be taken into account to be more effective in trying to improve the patient's nutritional intake.

Thirdly, an application will be developed that serves as an advisory tool for the patient. The goal is to get patients' nutritional intake as close as possible to their dietary needs. In order to know whether the nutritional intake of the patient is improved by using the application, the nutritional intake has to be measured. Monitoring consumption is important, because without it, it is impossible to know whether the experiment had any effect. It also makes it possible to show the patient how much more he needs to consume to reach their nutrition goal.

Information about what and how much nutrition a patient has consumed can as well be useful for medical staff.

1.3 Research questions

To carry out the activities mentioned in the previous section, research questions have been formulated. The main question of this research will be:

Can a tablet application improve hospital patients' nutritional intake?

The main research question is split up in three sub questions:

- Why do hospital patients have malnutrition and what is being done about it?
- How can general theories of persuasive technology be adapted for improving nutritional intake of hospital patients?
- How can a tablet application persuade hospital patients to improve nutritional intake?

1.4 Structure of the report

The reasons for people to have malnutrition have to be found out by interviewing nurses and nutritional experts. Besides that, literature will also be consulted for possible explanations. Reasons and solutions for malnutrition are discussed in chapter 2.

To improve the nutritional intake of patients, they have to be persuaded to improve their intake. Various persuasive technology theories will be studied and described. This, and ways for adapting the persuasive theories to making them applicable for a tablet application for hospital patients, can be found in chapter 3.

The application's functionality is described in chapter 4. Next step is the design and usability testing (chapter 5) for the actual implementation of the tablet application (chapter 6). The application will be tested in a hospital, and to see whether the application will have the desired effect, a small experiment will be set up. The methodology of the experiment is discussed in chapter 7, which is followed by the experiment results (chapter 8).

The report closes with a reflection on the discussed theoretical foundations (chapter 9) and conclusions including answering the research questions, discussion of the limitations and mentioning future research possibilities (chapter 10).

1.5 Aalborg hospital background information

Interviews and testing out the application will be done in the hospital of Aalborg. Aalborg is the third largest municipality in Denmark, situated in the northern part of Denmark, with a population just under 200 000 inhabitants (Danmarks Statistik, 2011). The hospital is responsible for 250 000 people for basic hospital functions, for 490 000 people as a regional function, and for 640 000 people as highly specialized regional function. Around 6 500 people are employed by the Aalborg hospital (Aalborg Sygehus , 2012).

Interviews with three employees of the Centre for Nutrition and Intestinal Diseases of the Aalborg hospital made clear how the hospital is providing

nutrition to their patients. Dinner is prepared in the central kitchen, put in large trays, and served decentralized on the wards. Food that is not prepared in the kitchen, e.g. snacks and drinks, are stored in a cupboard of the ward and distributed by the wards' nurses. Food is put on the plate of the patient on the ward, and not in the kitchen. Half of the wards have their own kitchen; they receive ingredients from the kitchen and do the cutting, but also receive semi-finished meals that they only have to warm up. The other half of the wards only receive finished products they can serve immediately.

Patients cannot make an advance choice for their food, as is usual in some other hospitals. There is therefore no paper (or digital) ordering list for patients. When the nurse serves the dinner, the patient has often (but not always) the choice between two menus.

Aalborg hospital has around 900 beds available for the intake of patients. According to the interviewees, around 40% of the patients have nutritional problems. The intake of these patients is measured for two consecutive days, after which nutritional experts can decide whether to take additional actions to increase nutritional intake. More information about the procedures of the Aalborg hospital, especially related to handling malnutrition, can be found in sections 2.4 and 7.1 to 7.3.

1.6 Ethical approval

Because the tablet application that was developed was tested in the hospital with patients, an application for an ethical committee was considered. After consideration with the head of research for nutrition in the Aalborg hospital, it became clear that because of the testing set-up and the results not being published in a medical journal, it wasn't necessary to apply for ethical approval.

1.7 Standards in this report

As with all scientific literature, there can be some discussion about standards used. Scientific literature offers unfortunately no consensus in the use of the comma and points for numbers (Williamson, 2008). The International System of Units (abbreviated to SI) and has declared that either a point or comma can be used for a decimal marker (BIPM, 2003). Because of its European roots, this report uses a comma as decimal separator. Larger numbers are separated in groups of three with a space, as the SI advices not to use dots or commas for this. Furthermore, for the (abbreviation of) units (e.g. kg, mL, cm) the SI is used in this report (Bureau International des Poids et Mesures, 2006). Lastly, *he* or *his* in this report can also be read as *she* or *her*.

2 Causes and solutions of malnutrition in a hospital

Before trying to improve the nutritional intake of hospital patients, it is important to know why this is a problem for patients in the first place. Besides mentioning the causes, this section will also discuss proposed ways of solving malnutrition. Although the focus of this research is more on patients instead of hospital employees (as explained in section 1.2), it is also important to know why hospitals have malnutrition. The problem of malnutrition in hospitals in general is discussed in 2.1, with a more detailed discussion of serving food in section 2.2. The reasons of patients for non-consumption are described in section 2.3. How malnutrition is currently solved is discussed in section 2.4.

2.1 Occurrence and reasons for malnutrition in hospitals

In a study by McWhirter & Pennington (1994), it was showed that on the admission of 500 patients, 40% had undernourishment and 34% were overweight. A reassessment of 112 patients on discharge showed that weight loss had occurred in 69% of the overweight patients, 39% of the normally nourished patients and 75% of the undernourished patients. Weight gain had occurred in 7% of the overweight patients, 21% of the normally nourished patients and 25% of the undernourished patients. Overall, all nutritional status groups were worse off than when they entered the hospital.

When the nutritional intake becomes too low, hospitals can intervene. In a study 18% (10 out of 55) of the undernourished patients were referred for nutritional support. This nutritional support is parenteral feeding (intravenously, bypassing the digestion) or through a feeding tube (that goes directly into the stomach). 70% of the patients who were referred for nutritional support gained weight, while 80% of the patients who were not referred lost weight (McWhirter & Pennington, 1994). While nutritional support like this seems to be effective, it is an unnatural way of feeding, not pleasant for the patient and does not solve the reason why the patient isn't eating in the first place.

An attempt by Lassen, Kruse, Bjerrum, Jensen & Hermansen (2004) to make medical staff aware of the importance of nutrition, had not conclusively the desired effect. During five months, two wards that were chosen for the intervention were given information about nutrition – Danish Recommendations for Hospitalised Patients – and were told to continuously fill in forms for the nutritional intake and risk assessment. One of the wards performed better after the intervention with higher energy and protein intake, but the other ward performed worse than before. During interviews and focus group meetings, nurses noted that because of the intervention they paid more attention to the diet and it became clear that nutrition is important. But on the other hand, nutritional records were often not filled in and nutrition was not really seen as the core-task of nurses. Time limitations of the nurses was the cause of this, with nurses not having time to learn how the nutritional records worked and perceived it as an additional workload. Nutrition by itself had sometimes been neglected because of a tight work schedule; as a nurse said, offering an extra portion had on occasion be neglected "because it's nutrition and similar things which we must choose not to include when we are busy" (Lassen, Kruse, Bjerrum, Jensen, & Hermansen, 2004).

It is unfortunate that in reality nurses have very limited time in providing nutrition to patients. In a study looking at the food served, breakfast accounts for 17% of the energy intake, lunch and supper combined for 75% and the remaining 8% for snacks (biscuits in this case) (Barton, Beigg, MacDonald, & Allison, 2000). Increasing the snacks served, in combination with fortified meals as an addition to the standard menu can increase energy intake of patients by 9% to 23% (different results in different wards). A disadvantage of more snacks is that of the additional 966 kcal/day served, only 25% was actually consumed and therefore the wastage was high. On some wards the protein intake decreased as well (Gall, Grimble, Reeve, & Thomas, 1998).

2.2 (In)adequate serving of meals

A reason for undernourishment can be that the patient doesn't get enough food in the first place; nevertheless this assumption is dismissed by several studies. In a four weeks study with 71 patients the food served and left over was examined. The hospital menu provided over 2 400 kcal per day, which is sufficient by itself. However, 30% to 42% of the food was not being consumed causing the food intake of patients being less than 80% of the recommended daily intake (Barton, Beigg, MacDonald, & Allison, 2000).

A research with a bigger setup (1 416 patients under investigation) showed comparable results. Of the average of 2 007 kcal provided by the hospital, 23% was not consumed, causing the average energy intake to be only 1 536 kcal. The total food intake of 43% of the 1 416 patients was below the minimum needs, and 70% was below the recommended needs (Dupertuis, Kossovsky, Kyle, Raguso, Genton, & Pichard, 2003).

Although the serving of food can be done in a correct way, patients can still miss a meal. During a two-week study in a Scottish hospital, over 2 000 patients were asked whether they missed a meal in the last 24 hours. On average, 21% missed a meal. Highest number of missed food was from the surgery department, especially patients returning after surgery missed 77% of the time a meal. The most frequently missed meal was breakfast (49%), after that lunch (33%) and then dinner (17%) (Eastwood, 1997).

2.3 Patients' reasons for non-consumption

In a survey set out to patients not eating all of their served food, they were asked for an underlying reason. The possible choices were inadequate cooking, taste, mealtime and no choice. A division was made between lunch and supper. Table 2.1 shows the results from this questionnaire; this already gives some insight into possible reasons for non-consumption. Only patients who didn't eat their entire meal were asked to answer this question, which were in total 1347 patients. (Dupertuis, Kossovsky, Kyle, Raguso, Genton, & Pichard, 2003).

Table 2.1: Reasons given by patients for non-consumption. Source: Dupertuis et al. (2003).

	Lunch	Supper
Inadequate cooking	101 (11%)	55 (6%)
Inadequate taste	182 (19%)	148 (17%)
Inadequate mealtime	66 (7%)	71 (8%)
No choice	160 (17%)	153 (17%)

An important factor for malnutrition can be the disease or treatment of the patients. But surprisingly, when asking the nurses if the disease and/or treatment has influence on a particular patient that eats less than the recommended consumption, the result is not extremely high. For 947 patients that did not eat all the food served, 26% of the nurses answered the disease and/or treatment was the predominant reason for eating insufficient, 22% believed this was the partial cause, 36% answered it was unrelated and 17% doesn't know (Dupertuis, Kossovsky, Kyle, Raguso, Genton, & Pichard, 2003). It is interesting to see that nurses believe that more than one-third of the undernourishment of patients is not caused by disease or treatment.

In a Danish hospital comparable to the hospital in this research, scientists concluded that the lack of knowledge of patients that they were given a choice of menu increased the risk of malnutrition. In this study of Lassen, Kruse & Bjerrum (2005), 80 out of 90 patients didn't know about the existence of a kitchen information folder, and only 33 of 90 patients were aware that there was a menu of the day (of which 3 heard from the staff, 26 found out themselves and 4 received the information from visitors or fellow patients). Also, 90% of the patients hadn't discussed nutritional intake with staff. This made the researcher conclude that the nursing staff exercised a "knowledge monopoly" by withholding information about food service from patients. This keeps patients "in a position of gratitude and dependence and the patients' own motivation for participating in the nutritional care is not utilized" (p. 265). Despite this harsh conclusion, patient satisfaction rates were high with 89% to 95% of the patients 'very satisfied' or 'satisfied' with the main meals. As one patient put it, "I have nothing to complain about. We must take whatever comes. We have to adapt to the hospital. The hospital cannot do things our way" (p. 262) (Lassen, Kruse, & Bjerrum, 2005).

The research of Lassen et al. (2005) also gathered remarks from patients during handling of the questionnaire. This qualitative information is given by a small minority of the patients, and is therefore absolutely not representative. Nevertheless, it can be useful to get insight into possible explanations for non-consumption; reasons for non-consumption mentioned by patients are:

- Between-meals (2pm after lunch and 8pm after dinner) were too soon after main meal so the patient wasn't hungry. But between 8pm and breakfast next morning was too much time.
- Time to eat was too short; the staff began to clean up before the patient had a chance to finish.

- There was too much disturbance, e.g. from doctors doing their rounds.
- The second round for food was too short after the first; while some patients were finished, others weren't and hadn't got a chance to take a second round.
- Especially when two dishes are served warm (e.g. soup and main dish), one is often cold when the first is finished. But in general, the dishes were served warm enough.
- Some foods were difficult to chew on (e.g. meat in slices or lumps).
- Some fruits (e.g. oranges) were not possible to peel by some patients.
- Not liking something (e.g. fish). It's not possible to get something else instead.
- Requesting a dietitian's advice was unsuccessful, because there would be "a long waiting list".
- Some rooms had a dining section, where patients could sit down. Not eating at the bed or having conversations with other patients could improve the appetite.

In a study comparing serving food on plates to a bulk system, patients were also asked why not all the food that was served was consumed. The number of patients filling in the questionnaire was not very high (37) and answers were very diverse, so conclusions from the results cannot really be drawn. But the list of 23 possibilities still offers insight into possible reasons for non-consumption, since all of the possibilities have been chosen by the patients at least once. The possible reasons for not consuming everything that was on the plate, are displayed in table 2.2 (Kelly, 1999). A distinction has been made between food related and patient related reasons. The patient related reasons are further categorized in condition of the patient, inadequate support and environmental reasons.

Table 2.2: Reasons for non-consumption in the research of Kelly (1999)

Food related reasons:	**Patient related reasons:**
• **Portion too large** • **The appearance/presentation of food** • **Familiar foods not on the menu/not enough choice** • **Food not the right temperature** • **Not enough sauce or gravy** • **Did not like the taste** • **Did not like how the food was cooked** • **Type of meal inappropriate for the time of day** • **Meal inappropriate for the weather** • **Lacks salt/tasteless** • **Culturally unacceptable**	**Condition of patient:** • **Patient too sick** • **Problems with chewing and dentures** • **Swallowing problems** • **Patient not hungry** **Inadequate support:** • **Food taken away from patient too soon** • **Patient has difficulty reaching food** • **Assistance in feeding not adequate** • **Feeding aids not provided/not appropriate** • **Patient not in appropriate eating position**

• **Food not sweet enough**	**Environment:** • **Different meal times than at home** • **Patient doesn't like eating with others**

A factor that can also play a role in the decreased nutritional intake, is the hospital environment the patient is in. When patients are stimulated to eat together in a dining room, food intake can increase by up to 36%. In this case there were on average eight patients in the dining room, eating lunch together, under the supervision of nursing assistants. Their nutritional intake was compared to regular hospital patients having lunch at their bedside (Wright, Hickson, & Frost, 2006).

Eating together can lead to an increased intake, but also increases the duration of the meal, which allows people to eat more. This increased duration of eating is called 'time extension' (De Castro, 1990). An explanation why social interaction increases nutritional intake, can be that a cognitive demanding task can be distracting; listening, talking and looking at others diverges attention away from the meal. This may impair self-monitoring and can lead to increased food intake (Bellisle & Dalix, 2001). Interestingly, the opposite happens as well; when asking people to focus on the taste of food (by rating it), the food intake decreases (Hetherington, Foster, Newman, Anderson, & Norton, 2006). It appears that distraction in general can increase nutritional intake, as eating in front of the TV can significantly increase intake by 14%. Social interaction during eating with two friends increased intake even more (18% compared to eating alone); eating with two unfamiliar people increased intake compared to eating alone, but not significantly (Hetherington, Anderson, Norton, & Newson, 2006). It has to be remarked that the distraction theories for improving nutritional intake have not been studied in a hospital situation, but only looked at healthy people.

2.4 Current solutions for malnutrition

In the case with Aalborg hospital, interviews with nutritional experts and nurses pointed out how this hospital tries to prevent malnutrition. This procedure is recommended by the Danish National Board of Health (Kondrup, Rasmussen, Hamberg, & Stanga, 2003) and the European Society for Clinical Nutrition and Metabolism (Kondrup, Allison, Elia, Vellas, & Plauth, 2003). All admitted patients that are probably staying longer than 48 hours (except women giving birth or terminally ill patients) undergo a nutritional risk screening. Height, normal weight, weight on admission and BMI are noted. Four indicators are used: weight loss in last 3 months more than 5%, food intake decreased in last week, BMI under 20,5 and whether patient is severely ill; if one is true additional questions are asked. Nutritional status (weight loss, nutritional intake), severity of illness and age provide a score, and if the score is above a certain level, nutritional intake has to be monitored. This nutritional risk screening is repeated every seven days for all patients in the hospital.

When the monitoring of nutritional intake of the patient turns out that the intake is too low, additional measures can be taken. First the patient can receive fortified meals. Secondly, the patient can receive drinks with high amounts of

calories and proteins (up to 2kcal/mL, so 1 litre is enough to live on for a day). Thirdly, the patient can receive tube or parenteral (intravenously) feeding in combination with normal feeding. And fourthly, the patient can receive only tube or parenteral feeding. This is for Aalborg hospital the order of preference for nutritional intake; the more natural intake the patient can have, the better.

It is interesting to see that with the current monitoring systems of weekly doing a nutritional risk screening, the hospital can only take action when undernourishment has occurred. It is understandable, because intervention for all patients is time consuming and expensive. And motivating patients to eat is also difficult. In a similar field with undernourished patients, namely anorexia nervosa patients, the first priority is similarly the feeding of patients and secondly, when the patient is recovered enough, the treatment of causes for the undernourishment (psychiatric problems). Medication usage has limited merit, and should not be the first choice of treatment. For anti-depressives and anti-psychotic medication, zinc supplements and Cyproheptadine (appetite stimulator) there is no convincing scientific proof that they increase weight and are therefore not recommended as treatment (Landelijke Stuurgroep Multidisciplinaire Richtlijnontwikkeling in de GGZ, 2006).

Prevention of malnutrition or attempting to decrease the severity before it is too late, would really be beneficial for patients' health. Some monitoring tools are implemented in the hospital, but when looking at weight loss and not nutritional intake, the undernourishment has already occurred. Continuous monitoring of all nutritional intake (instead of weight) for all patients would be better. However, it is understandable that because of time and budget constraints, the limited resources are utilized for the care of the most undernourished patients. But it would be better to prevent it from getting this far.

3 Persuasive technology theories

When trying to improve nutritional intake of patients, it is important to know how patients can be persuaded to change their nutritional intake. This requires a change of behaviour or attitude, which is achieved by persuasion. There are numerous persuasion theories from the psychology (in particular sociology) research area, but this chapter will particularly focus on theories that are highly applicable to (the development of) the nutritional tablet application. Because of the technical aspects, a more specific research field of persuasion is also involved, namely persuasive technology theories.

The research area of persuasive technology is relatively new since the early computers were more focussed on productivity and processing data, but can nowadays make personalized suggestions and are more integrated in our lives (Fogg, 2003). Characteristic about persuasive technologies is that they "deliberately attempt to infuse a cognitive and/or an emotional change in the mental state of a user to transform the user's current cognitive state into another planned state" (Torning & Oinas-Kukkonen, 2009, p. 2). The area of persuasive technology is sometimes also called captology, as an acronym for Computers As Persuasive Technologies (CAPT-ology) and emerges from the Conference on Human Factors in Computing Systems of 1997 (Fogg, 1998). This chapter will mention some of the theories that are developed for this research field and are useful for the realization of the nutritional application.

Because of time limitations it is not possible to do a complete literature study to all available persuasion (technology) theories. However, the goal of this chapter is not to discuss all possible theories, but it is to support the development of the nutritional application to be more effective. By exploring the captology field, general persuasion theories and even looking into sociology literature and books, it can be said with fair confidence that these theories are most applicable for this project. Nevertheless, the theories are general, and specific handling of the problem of increasing nutritional intake by using persuasive theories has not been found in scientific literature. All six sections discussing a persuasion theory will therefore also state how the theory can be applied for this particular project. Specifics about how the theory will be incorporated in the functionality of the application can be found in section 4.3.7.

First two general persuasion theories related to change are discussed; section 3.1 mentions the phases people have to go through to change and section 3.2 discusses how our mind tries to make sense out of things and can be tricked to change the beliefs. Then more technical persuasion theories are elaborated upon with in section 3.3 describing the process of designing persuasive technology and in section 3.4 discussing design principles of persuasive technology. Three important factors for persuasion technologies – ability, motivation and a trigger – are explained in section 3.5. This chapter closes with mentioning important characteristics of a persuasive message in section 3.6.

3.1 Stages of change

A model of Prochaska and Norcross (2001) describes six stages of change. This model is independent of technology, and is more a general theory. A person is in one of these stages, and over time can gradually go to a next stage. Each stage

requires a slightly different approach and tasks that need to be completed before moving to the next stage.

1. **Precontemplation**: the person has no intention of changing behaviour in the foreseeable future. Often people in this phase are unaware that there is a problem. Even though people can *wish* to change, that is still not the same as having a true *intention* of changing.
2. **Contemplation**: the person is aware that there is a problem and is seriously thinking about overcoming it, however the individual has not yet made a commitment to take action.
3. **Preparation**: the person is planning to take action in the very near future and sometimes has already attempted to take action which failed.
4. **Action**: here the individual actually changes his behaviour. This stage is the most visible and has the most external recognition.
5. **Maintenance**: after the change it is important to work on the prevention of relapsing.
6. **Termination**: this is the completion of the change process. The person no longer has to work to prevent relapse.

Because the model is explained by the authors with examples of getting rid of an addiction, the timeframe of the stages are then multiple months. In this project with hospital patients the timeframe is a lot shorter. However, it is useful to know the specific stage the patient is in, since every stage requires a different approach. Patients in the precontemplation stage need to be made aware of the problem and patients in the action stage can receive tips on how to improve. The patient namely first needs to be aware that there is a problem, and after that can start doing something about it (e.g. changing the nutrition to something that can be easier swallowed). After deciding the current phase of the patient, the application can try to move the patient to the next phase.

3.2 Cognitive dissonance

Cognitive dissonance theory is looking into the situation the person that has to be persuaded is in. Cognitive dissonance theory is first described by Festinger (1957). Relations between cognitions (thoughts or ideas) can be: consonance, dissonance or irrelevance. When two beliefs are that *I don't like being in the hospital* and *I would like to recover fast*, they are consistent. Another cognition can be introduced – e.g. *I love to see my family and friends* – which is completely irrelevant for the other cognitions. But having the cognition *I don't like to eat* is in conflict (dissonance) with the wish to recover fast.

There are three ways to restore consonance: change the cognition (*I do like to eat*), add a new cognition (*I just never really tasted to food very well, I really must try out some other menu options*) or change the importance of cognitions (*I don't think that eating more will help me with my recovery*). An important limitation of cognitive dissonance theory is that it doesn't predict what the person is going to do to decrease the dissonance. And creating dissonance in the hope that desired attitude change would result is tricky, since there are other cognitions (which can create dissonance) as well and the result is unpredictable.

Dissonance can also occur when having to choose between options. Especially when the decision is important or the desirability of the options is high, the

amount of dissonance experienced is high (Festinger, 1964). There are four ways of reducing the dissonance after making the decision: revoking the decision, increase the attractiveness of the chosen option, decrease the attractiveness of other non-chosen options, or reduce the importance of the decision. A common way is to adopt both the second and third way, by which the chosen option and alternatives appear further apart than before, and therefore having less dissonance (called the spreading effect) (Benoit & Benoit, 2008).

A very insightful study is from Festinger & Carlsmith (1959) describing the concept of forced compliance, or in other words, what happens "to a person's private opinion if he is forced to do or say something contrary to that opinion". In the experiment the test subject had to do a very boring task for one hour. After that, one third was given the option to convince the next participant (which was actually a confederate) that it was a fun experiment to do and was offered 1 dollar for that; another one third of the test subjects had to do that as well but were offered 20 dollar and the last third was the control group and did not hear anything about a next participant. Afterwards, they had to rate the enjoyability of the experiment, which was slightly higher for the $ 20 group compared to the control group. But the $ 1 group enjoyed it a lot more, which was explained by the researchers that the test subject had to truly believe that it was exciting and fun to do. The $ 20 group could rationalize it by believing that they said that it was fun to do because they got $ 20 for it. The $ 1 group had no justification for this dissonance, and most likely had to change their attitudes towards the task. "The less justification [that] is provided for performing the counter-attitudinal behaviour, the more the attitude will change" (Benoit & Benoit, 2008, p. 174).

One of the results mentioned in the cognitive dissonance theory is that the reward should not be big; otherwise the user will do the improvement for the reward. Instead, the user should believe in it that it is important and that the change comes out of his-/herself.

When a patient constantly decides to eat too little, the application could increase dissonance by making the option of eating something more attractive, decrease the attractiveness of eating too little and increase the importance of the decision. In general dissonance can also be increased, by showing the contradiction of not having good nutritional intake, while wanting to recover swiftly. There are three things that can happen: change the cognition (e.g. starting to like eating), a new cognition (e.g. trying out new menus) or change the importance of cognitions (e.g. believing not eating doesn't have influence on recovery). Although the theory suggests that it is difficult to predict which of the three consequences will occur, the application should try to steer the patient in the right direction (e.g. trying out other food).

3.3 Eight step design process

When creating some kind of a persuasive technology, it can be useful to have some guidelines for the design. An example of a design process of persuasive technology is that of Fogg (2009a). The problem with most persuasive technology projects is that they often fail, because of too high ambitions. When the goal of an application would be to let users stop smoking entirely, it can be expected that this is too difficult because many (failed) attempts for this have already been made. It would be better to start small with tractable behaviour

changes. The eight-step design process is intended to increase the success of persuasion by starting small and iteratively improve on success.

The eight steps of the process are displayed in figure 3.1 and are carried out mostly in sequence, but it is also possible to execute steps in parallel. Changing the sequence of steps or going back and forward is also possible.

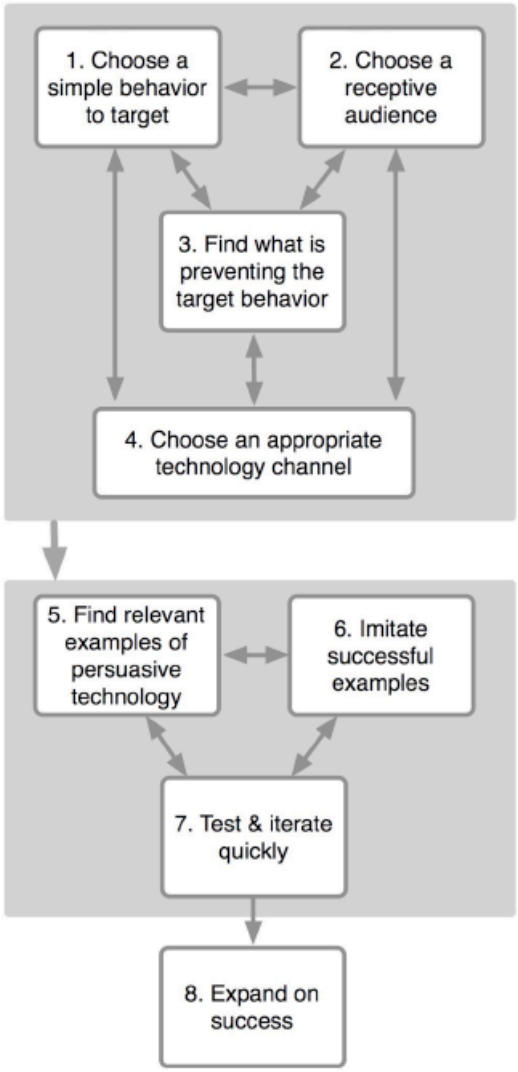

Figure 3.1: Eight-step design process by Fogg (2009a)

As can be seen in the figure, there is a division between the first four steps and the remaining steps. It is important that the first four steps are completed before moving on to step five. Step number eight is the final step and will continuously be executed, because the project can always be improved. The order and starting point of the first four steps can differ, since for some projects the audience is fixed or a specific behaviour to target is already decided upon. The order of the steps is less important, it is more important to find the right combination. A more detailed explanation of the eight steps is given below.

1. **Choose a simple behaviour to target**: The first step in the persuasive technology design process is choosing the target behaviour. The goal should be to achieve behaviour that is simple, small and measurable. A small goal may not seem very useful, but convincing people to do something small can be a first step for something bigger or lead to a change of thinking. When the goal would be to make people aware of sustainability, changing a light bulb to a low-energy variant makes people start thinking about the environment.
2. **Choose a receptive audience**: the targeted audience shouldn't include everyone, but make a very limited selection. This helps in increasing the chances of success for the project. The author gives an example of persuading people to improve their eating habits; a target audience should be selected that already demonstrated a desire to improve their behaviour. The audience should be receptive to the targeted behaviour change and familiar with the technology channel (explained in step four).
3. **Find what is preventing the target behaviour**: when trying to improve certain behaviour on a certain target group, it is important to know what is preventing them from performing that targeted behaviour. There are three reasons for this: a lack of motivation, ability and/or trigger. With

the example of the more energy efficient light bulb: people should see the advantages of it, have the money for it, and someone/something should point out that it is better. These three factors are explained in more detail in section 3.5.

4. **Chose an appropriate technology channel**: which channel is best to communicate through depends on the outcome of the previous three steps. The communication channel should be familiar to the users and they should be willing to work with it. For example, senior people often don't have a smartphone and using social platforms as Facebook won't work for them. Choosing the right technology channel is also dependent on what is preventing the behaviour (step 3); some technologies are better in improving the motivation (e.g. messages, social platforms), while others can increase the ability (e.g. showing a map where to buy low-energy light bulbs).
5. **Find relevant examples of persuasive technology**: after the first four steps are completed, the designer can continue to this step. Finding similar successful persuasive technology examples helps to find out what works. The author advises to look for three examples that achieve similar behaviour, three examples targeting the same audience and three that use the same technology channel (so in total nine examples).
6. **Imitate successful examples**: there is no need to reinvent the wheel. The examples of step five can be applied in the project, but it can be difficult to find the "secret sauce" of the exact technique that makes it so successful or the combination of correct techniques. Although copying exactly is not the intention here, but imitating the techniques (and not the technology) is the fastest and surest way to create successful persuasion.
7. **Test & iterate quickly**: the goal of this step is finding something that works. Multiple small attempts will have to be made before something is found that has the desired effect. It is therefore advised to keep tests small and rapid, to see how the users react to the prototype. Every test will help the designers in gaining insight into the success factors.
8. **Expand on success**: once there is success in persuading users, the project can be expanded. This is a continuous process and can be seen as the final step in the design process. There are multiple options to expand: the target group can be expanded with more users or including another (more difficult) target group, expand the persuasion target behaviour or improve the compliance rate.

The eight-step design process is intended to increase the likelihood that the development of the persuasive technology will succeed. Unfortunately, for this research project there are time limitations, and as will be explained in section 7.5, testing the application will take about a month and before that it needs to be completely finished. Step 7 – test & iterate quickly – is therefore not entirely possible, since there is one final test in the hospital and before that time the application has to be completely finished.

The chosen simple target behaviour (step 1) is to improve the nutritional intake; the more difficult ultimate goal is to have an increased recovery. Making the targeted behaviour easier than improving the nutritional intake, is almost

impossible or does have marginal effect on the patient's health (e.g. eating one slice of bread extra, but that could result in less appetite for dinner). Choosing a receptive audience (step 2) is unfortunately not possible, since the patients have to be recruited from the hospital, and finding participants willing to cooperate in the study for a prolonged time is already a challenge. Limiting the target group would also bias the generalisation of the results and limit conclusions in the end. Reasons preventing the target behaviour to take place (step 3) have already mainly been discussed in chapter 2. The technology channel (step 4) that has been chosen is a tablet application; for more information about this decision see section 5.1.

Looking for relevant examples (step 5) is not really possible for the target group, since this is too broad. There are numerous examples of persuasive technologies using a tablet application, since there are at the moment more than 550 000 applications for the iPad and iPhone, and more than 170 000 native iPad applications available (Apple, 2012). Examples of achieving similar behaviour can be from e.g. anorexia applications accessing the severity and calculating the BMI, nutritional advise in the form of the amount of calories and vitamins to be consumed, or recipes for making a balanced meal. The applications found to be similar to this project shall be used for the development (step 6). Testing and iterating (step 7) will be done less than requested from the framework, as explained above. The expansion on success (step 8) with points of improvement will be discussed in section 10.3 concerning future developments of this project.

3.4 Persuasion design principles

Another help in designing and evaluating persuasive technology is the framework of Oinas-Kukkonen and Harjumaa (2008). It describes "what kind of content and software functionality may be found at the final product" and can as such be used as a requirements document. The authors make a distinction between four categories necessary for a persuasive system: primary task support, dialogue support, system credibility support and social support.

The first category, primary tasks support, is about supporting "the carrying out of the user's primary task". There are seven so called "design principles" in this category:

- **Reduction**: reducing (complex) behaviour of the user. This can be done by creating simple tasks and increasing the cost/benefit ratio. An example would be that the system should reduce a certain effort in regard to perform a certain action, e.g. the system shows the healthy menu options in a fast-food restaurant.
- **Tunnelling**: the system guides the user through a process or experience, and along the way uses opportunities for persuasion. For example, after entering an online questionnaire about addictions, the system can provide smoking treatment opportunities.
- **Tailoring**: when using personal information from users (e.g. interests, usage context, personalities, potential needs) to tailor the information to the user group has more persuasive effect.
- **Personalization**: offering personalized content or services has greater persuasion effects. This can be to change the graphical layout of the

interface, making a personalized index page or change the ordering of data.

- **Self-monitoring**: the system helps track the performance of the user by showing the performance and goal-achievement over time.
- **Simulation**: show the user the link between cause and effect in regard to their behaviour. For example, showing before and after pictures of people losing weight or the improved health statistics of people that stopped smoking.
- **Rehearsal**: when the user can use the system to try out alternative behaviour, the user could adapt this behaviour in the real world as well (e.g. a flying simulator).

The second category of the design principles is dialogue support between the computer and user. It helps the user to keep moving towards its goal or target behaviour.

- **Praise**: by giving positive feedback the user will be more open to persuasion. This can be done via images, words, sounds or symbols.
- **Rewards**: when reaching a target this can be rewarded with a virtual trophy (e.g. skill-level, trophy, music or unlocking maps).
- **Reminders**: reminding users of their target behaviour increases the chance of achieving the goals.
- **Suggestion**: suggesting certain behaviour (e.g. eat fruit instead of candy) at opportune moments can have great persuasive powers.
- **Similarity**: imitating the user (e.g. slang names for teenagers).
- **Liking**: if the look and feel of the system is visually attractive to users it is likely to be more persuasive.
- **Social role**: the system supporting communication between other users and possibly specialists.

The third category is about the system credibility. When the system is more credible, it has more persuasive powers.

- **Trustworthiness**: the system should be truthful, fair and unbiased. For example, a company website providing product information instead of advertising or marketing information.
- **Expertise**: when the system is knowledgeable, experienced and having competence (e.g. website updated regularly and no dead links).
- **Surface credibility**: first-hand inspection of competent look and feel of application (e.g. not a lot of banners) is important.
- **Real-world feel**: highlighting people or organizations behind the content or services will increase credibility.
- **Authority**: the system refers to people or organizations that are credible (e.g. government health office).
- **Third-party endorsements**: there are third-party endorsements from respected well-known sources (e.g. branch certificates and guarantees).
- **Verifiability**: if the accuracy of the content of the application is easy to verify, the credibility perceptions will be enhanced (e.g. claims made on a website have links referencing to external sites).

The last and fourth category is social support. Using social influence can motivate users.

- **Social learning**: when the person can see the performance of other users, the person will be more motivated to perform a targeted behaviour.
- **Social comparison**: not only seeing the performance of other users, but also being able to compare the performance of the user with the performance of other users.
- **Normative influence**: peer pressure from friends/family or other people with similar goals helps because it sets a norm.
- **Social facilitation**: it encourages the user when he/she can see that there are others that are performing the behaviour along with him/her.
- **Cooperation**: working together with other users to reach a goal.
- **Competition**: competing with other users is a natural drive of humans.
- **Recognition**: offering public recognition for a user (or group of people) who has reached his target (e.g. personal success stories or publish the winner).

The key of success is to find the right combination of design principles. A single design principle can work fine, but there can be a bigger effect (synergy) when combining it with another principle. However, combining principles can also have an adverse effect; e.g. the combination of tunnelling and reduction didn't work in the research of Räisänen, Lehto, and Oinas-Kukkonen (2010).

Many of the discussed 28 design principles can be used for the application. Design principles that are used and their specific implementation details can be found in section 4.3.7. Design principles that will not be applied in the tablet application, are mentioned in the bullets below including the reason for it.

- **Reduction**: this is not the intent of the application as the goal is to increase intake.
- **Personalization**: because of limited time, this has no priority. The only personalization available will be that the name of the user is used to address him/her.
- **Rehearsal**: this is not useful for the goal of the application.
- **Rewards**: there is no virtual world in the application, and virtual rewards would therefore be unusual.
- **Similarity**: because of the diversity of users, applying this design principle is difficult and wrong imitation can only lead to frustration.

3.5 Ability, motivation and trigger

According to Fogg (2009b) there are three factors that are important for behaviour: ability, motivation and a trigger. These factors must be in congruence with each other in order for the targeted behaviour to occur.

Ability and motivation are complimentary, and with a high motivation and high ability, the targeted behaviour is likely to happen. When there is enough motivation for people to reach a certain goal, but it is e.g. physically impossible (ability), additional motivational coaching isn't the solution. But to a certain extend, ability and motivation are interchangeable. Although the ability and motivation to buy a computer now would be low, making it very cheap increases

the ability and makes it more likely to persuade the person. The other way around is also possible: participating in a marathon is really hard (low ability), but rewarding it with a lot of money (increasing motivation) could help.

The author mentions that motivation can be increased by increasing pleasure / decreasing pain, increasing hope / decreasing fear or increasing social acceptance / decreasing rejection. Ability can be increased by simplicity, since people are by nature lazy. There are six elements that decide whether something is simple. All elements should work properly; if one element isn't simple, the entire process is difficult and ability is decreased. Ability can be improved by making it easy, which can be done by decreasing one of the six elements.

- **Time**: the less time it takes to accomplish the behaviour, the higher the ability.
- **Money**: making something cheaper increases ability.
- **Physical effort**: shopping online takes less trouble than going to a store.
- **Brain cycles**: not having to think too much about it is easy (especially if the user already has to think about a lot of other things).
- **Social deviance**: not going against the norm or breaking rules of society (e.g. not taking a shower after heavy sporting when meeting people).
- **Non-routine**: when people can stick to their routine, it makes it easier (e.g. someone buying product in a store he/she always visits, although it is a bit more expensive than other stores).

Besides the right amount of ability and motivation, it is also important that the person is triggered. This can be an alarm bell ringing or a received message. A successful trigger has three characteristics: it is noticed, a target behaviour is associated with it and the trigger happens at the right time when there is enough motivation and ability. The last characteristic – the timing of the trigger – is often the missing element in behaviour change and can cause frustration (when the ability is low) or is distracting (when the motivation is low). There are three types of triggers:

- **Spark**: this type of trigger stimulates the motivation of the user. This can be done by e.g. increasing hope by sending an email message that the user is on the right track with his workout schedule.
- **Facilitator**: this trigger is appropriate for users with motivation, but lack the ability. It tries to make the targeted behaviour easier to reach, e.g. by explaining in a video how it should be done or an alert telling that the software update can be installed in only one click.
- **Signal**: triggers like these don't have any motivational element or are trying to make it easier. It just serves as a simple reminder, e.g. a traffic light turning red.

Ability is the biggest factor preventing nutritional intake. When the person is not ill, he/she will probably have no or less nutritional intake problems. Less nutritional intake is directly related to being in the hospital thus being ill. Ability can be improved by making things easy, which is decreasing one of the six elements (time, money, social deviance, physical effort, non-routine and brain cycles). Time is not an issue, since patients in the hospital are not particularly stressed out. Money also not, since hospital nutrition is free. Social deviance is not a factor and physical effort is even less in the hospital than having to make

dinner yourself. Non-routine is something the hospital decides with meal times and therefore not changeable by the application, although the meal times are very frequent. Brain cycles is the only element that can be influenced by the application, since too many menu choices could be difficult, and the application could make suggestions. Although it is expected that the amount of menu choices is not really decreasing ability, because for making lunch or dinner yourself you have to think more about the choices (in other words, the hospital already decreases the brain cycles for the patient). All in all, the application can barely make any changes to improve the ability of the user.

A low amount of ability can be compensated by a high amount of motivation. This can be done by increasing pleasure / decreasing pain, increasing hope / decreasing fear or increasing social acceptance / decreasing rejection. Decreasing pain is not something the application can do (but is something for the doctors) and social rejection will probably also not influence the appetite of the patient (unless he/she is in for anorexia). In the theories discussed in chapter 2, fear did not come up as a reason for having nutritional intake problems. The application will therefore focus on increasing motivation by increasing pleasure, hope and social acceptance.

The third aspect – the trigger – will be an important part of the application. Because the motivation needs to be increased, particularly a spark trigger will be applied. The trigger must be noticed, have a target behaviour associated with it and must be at the right time when there is enough motivation and ability.

3.6 Persuasive messages theories

A persuasive message could only mention the arguments in favour of the persuader; these are called one-sided messages. But it is also an option to mention arguments on behalf of both the persuader's position and the opposition; this is called two-sided communication (Perloff, 2010). It appears that two-sided communication increases the credibility and effectiveness (Kamins, Brand, Hoeke, & Moe, 1989). This is however only true when the arguments from the opposite party are refuted instead of only mentioning them (O'Keefe, 1990).

The way that we receive the persuasive message also influences the effectiveness. When we overhear a conversation, read something that was not intended for us or in another way believe the sender is unaware that we receive his message, it will increase the persuasiveness. This can possibly be because we don't expect it to be intended as a persuasive message, since the message is not intended for us, and therefore our guard is down (Walster & Festinger, 1962).

Knowing that the message is meant to be persuasive can negatively influence the effectiveness of the persuasion (Dean, Austin, & Watts, 1971). People are warned about the influence (which is called forewarning) and can for example rehearse counter-arguments (Hogg & Vaughan, 2008).

When the personal freedom of someone is being threatened, e.g. when that person has three options and learns that one of the options is eliminated, he/she could experience reactance. The person will attempt to restore the loss of freedom. The magnitude of reactance is related to the importance or proportion of "the free behaviors that are eliminated or threatened" or the magnitude of the

threat (Brehm, 1966). Forcing someone therefore by persuasion to go into a certain direction and limiting the options, could lead to reactance and negative attitude change (Hogg & Vaughan, 2008).

As for the messages of the application, they should be two-sided, stating arguments for not improving nutritional intake. But it is important to counter these opposite arguments as well.

It is important not to state clearly that the goal of the application is to persuade the user to improve nutritional intake. Although lying about it can make the user angry or feel mistreated. The application should not lie about the intentions, but also not state them too clearly.

Forcing the user to e.g. have a limited menu choice is probably also not a good idea. Decreasing the user's freedom will lead to reactance, which will not have the desired results.

4 Application functionality

This chapter discusses the first step in the creation of the nutritional intake application. Development of software in general can be done with a structured technique of subsequent activities, called the software life cycle (Dix, Finlay, Abowd, & Beale, 2004). The graphical representation of this life cycle is "a waterfall, in which each activity naturally leads into the next". First step is specifying the requirements of "what the system will be expected to provide", but also how the system is going to provide this (called the "architectural design"); this is specified in this chapter. Next is the creation of a detailed design (covered in chapter 5) and coding/testing the application (discussed in chapter 6). The software life cycles closes with integration & testing (when multiple components are created and have to be combined) and finally maintenance; both are not applicable for this particular project.

Although the software life cycle can be considered as a waterfall, as progression is made new information is obtained, and feedback to previous step(s) is given. The design process is in reality iterative with changing requirements discovered during the design and implementation phase. This can be dealt with by using prototypes that are improved step-by-step (iteratively) (Dix, Finlay, Abowd, & Beale, 2004). Nevertheless, time limitations don't allow this project to develop multiple prototypes. Section 6.9 will reflect on changed functionality compared to the final application. In essence, this project can be considered one development iteration, with the final application as the prototype that can be further developed in future research.

The rest of this chapter describes the first step in development, namely the specification of functionality. When describing the functionality (or requirements) of the system, it is useful to make a categorization. A common distinction is between functional and non-functional requirements. Functional requirements are features the system provides. Non-functional requirements are "features of the system that are not directly related to the actual services provided but relate to the manner in which those services must be provided". Examples of specific non-functionality categories are: performance, reliability, safety features, usability and supportability (Dix, Finlay, Abowd, & Beale, 2004).

To get a global overview of the application, section 4.1 describes the application activities with a diagram. Section 4.2 will continue with the non-functional requirements and section 4.3 goes into more detail with the functional requirements.

4.1 Activity overview

To get a better understanding of the application, figure 4.1 displays an activity diagram of the application. To store information about the individual patients, a patient profile has to be created first, and after that a demonstration of the application is given. The patient can always ask for nutritional advice. Because one of the goals of the application is to change the selection of nutrition, the persuasion has to happen on the moment of nutritional selection or before that. The moment of selection is when the nurse is on the ward distributing the food and drinks, and because the tablet is on the bedside and the nurse is in the hallway, interaction at the moment of selection is not possible. Therefore, the

application gives a notification 15 minutes before mealtime to show the patient the menu options. Afterwards, around 30 minutes after mealtime, another notification will be given to ask the patient to enter what he/she has consumed and reasons for non-consumption. This information can then be used in future nutritional advice.

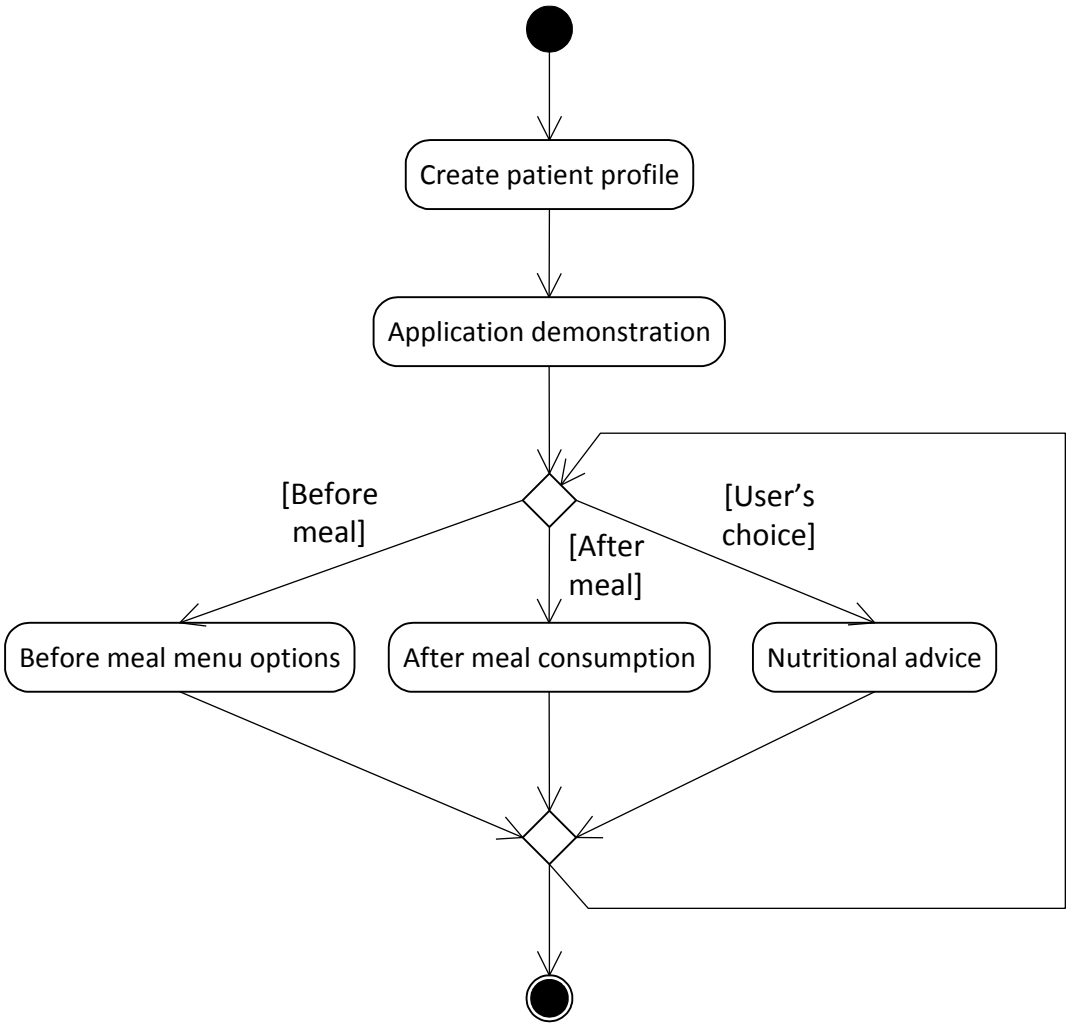

Figure 4.1: Activity diagram of the application

It must be remarked that the activity diagram isn't perfect. Certain activities or possibilities aren't included in the diagram, because that would clutter the diagram to the point of losing the overview (which was exactly the reason for creating the diagram in the first place). Functionality as notifications, possibility to start the demonstration again, having multiple profiles for different patients, etc. are specified in more detail in section 4.3.

4.2 Non-functional requirements

4.2.1 Performance

There are no real requirements in this category. The system must respond within "normal" time ranges in order for the user not to get frustrated.

4.2.2 Reliability

Information entered by the user must be stored. If the application would crash or the device would be turned off, the data must still be available the next time the user runs the application.

4.2.3 Safety features

Although the system is not connected to the hospital information system, the collected data has to be handled with care. Information the user has entered must only be transferred over the Internet via a secure connection. The application is not password protected, since the device is in the vicinity of the patient and information in the application is not really sensitive.

4.2.4 Usability

50% of the patients admitted in Danish hospitals are older than 60 years (Danmarks Statistik, 2010). This age group is often very unfamiliar with computer technology. Making the system intuitive and easy to learn is therefore a priority. Because of the older age group that has to be supported, icons shouldn't be too small since that can make the selection of options difficult.

At the first time use, the application has to explain its functionality by showing a demonstration of the possibilities. Specific help functionality or documentation for individual functions is not available.

4.2.5 Supportability

Supportability has many aspects: testability, extensibility, adaptability, maintainability, compatibility, configurability, serviceability, installability, localizability and portability (Chung & do Prado Leite, 2009). Most of these aspects are not applicable to the application, since it is a research prototype and not a production system for a company. Nevertheless, the system must support the English and Danish language and have an option to switch between them.

4.3 Functional requirements

4.3.1 Administrative settings screen

Some functionality should only be available to the researcher and not for the user. This is especially necessary for selecting the patient profile and sending user's data to an external server. The switching of language should also only be done by the researcher to prevent problems for users not understanding the English language after they switched to it from Danish. This leads to the following requirements:

Req. 1. The system must have an administrative setting screen.
Req. 2. The administrative settings screen is invisible and inaccessible for normal users, but can be entered by the administrative user.
Req. 3. In the administrative settings screen it is possible to:
  a. Change the language between English and Danish.
  b. Change the selected patient profile.
  c. Create a new patient profile.
  d. Send the data over a secure connection to an external server.

4.3.2 Patient profile

Information about the user is saved in a "patient profile". This makes it possible to retrieve and store information about the user currently using the application.

Req. 4. The system must support multiple profiles for different patients.
Req. 5. The system must select automatically the profile that was used the previous time.
Req. 6. A patient profile contains the following information about the patient:
a. Name
b. Nutritional intake records
c. Preferences and allergies

4.3.3 Demonstrating the application

To help understand the program and to be as consistent as possible when using the application for testing purposes, a demonstration of the application is provided. This shows the functionality of the application and explains how to use it.

Req. 7. The system must be able to demonstrate the functionality of the application.
Req. 8. The demonstration is consistent at all times for all users.
Req. 9. The demonstration can be executed at all times.
Req. 10. During the demonstration, the user has to agree with a disclaimer that the application is not a replacement for doctors' advise, recommendations from hospital staff should always be followed and common sense should be used.

4.3.4 Before meal menu options

As explained in section 4.1, the system asks the user 15 minutes before the start of the meal to plan the meal. This is done to let the user think about the nutrition before it is actually consumed. A special "before meal" functionality showing the possible nutrition options is necessary for this purpose.

Req. 11. The system will give an alert 15 minutes before the meal. With this alert the before meal screen in the application can be opened.
Req. 12. The system will show the menu options available, and requests the patient to enter what he/she is planning to have.
Req. 13. The system will advise the patient on nutrition.

4.3.5 After meal nutritional measurement

After the meal is consumed, it is important to know the actual amount consumed. To help the user not forget this, an alert is given. The "after meal" functionality is very similar to the "before meal" functionality explained in the previous section 4.3.4.

Req. 14. The system will give an alert 30 minutes after the meal. With this alert the after meal screen in the application can be opened.
Req. 15. The system will show the menu options the patient could have had and ask the patient what he/she got.

Req. 16. The system will request the patient to specify the amount of chosen nutrition that is consumed or left over.
Req. 17. The system will ask for reasons why certain nutrition is not consumed and satisfaction with the nutrition.

4.3.6 Nutritional advice

The main purpose of the system is to improve nutritional intake. This is done with persuasive elements explained in the next section 4.3.7, but also with simple advices. The system shows the recommended nutrition, compares it to the consumed nutrition and provides the user with advice about how to improve it.

Req. 18. The system has a screen with an overview of the consumed nutrition and nutritional advice.
Req. 19. A distinction is made between morning, afternoon and evening consumption. Less nutritional intake in the morning will result in larger advised nutritional intake in the afternoon and evening.
Req. 20. The system will base the nutritional advice on:
a. Ideal nutritional intake for the patient, compared to the already consumed nutrition.
b. Not only energy amounts, but also quality of selected nutrition (e.g. vitamins, fats, proteins).
c. Reasons for non-consumption of food (see req. 17).
d. General nutritional advice, e.g. eating brown bread is healthier than white bread.
e. Preferences and allergies of the patient (e.g. fish, lactose intolerance, pork meat).
f. Minimum fluid intake is not as precise as food advice, since there are no clear guidelines. Nevertheless, the system will give general recommendations and mentions several indicators for insufficient fluidal intake.

4.3.7 Persuasion theories elements

Various persuasive elements explained in chapter 3 will find its way into the system. A complete list of theories being used can be found in table 4.1, which shows how the different persuasive technology theories described in chapter 3 are incorporated into the functionality.

Req. 21. The system will use the name of the patient to address him/her.
Req. 22. The system will show possible results and consequences if the patient continues to under-consume. The system will give a rough estimate since exact predictions are too difficult and there are too many variables (kind of patient, condition of disease, history, motivation to recover, etc.) to predict the consequences of under consumption.
Req. 23. The system will not only give advice about how to improve nutritional intake, but will also mention the positive things or improvements (e.g. everything on the plate or all vegetables were eaten).

Req. 24. The system has a social platform in which the patient can communicate with other patients. The social platform will also show progression of other patients and an option to compare progression of the patient with others.
Req. 25. The system offers the option to post the progression of the patient to social media (e.g. Facebook or Twitter)
Req. 26. The system has the possibility to verify suggestions and advices with references from reliable external websites.
Req. 27. The system will show logos from Aalborg University, University of Twente and Aalborg Sygehus to show that these organizations are behind the system to increase credibility.
Req. 28. The system will try to increase motivation, by focusing on increasing pleasure, hope and social acceptance.
Req. 29. The notifications will have a motivational element in it (a spark trigger).
Req. 30. The system will account for the "stage of change" the patient is in and tries to advance the patient to the next phase.
Req. 31. The system will not give big compliments and other rewards, since that will rationalize the change and give justification for changing.
Req. 32. The system will try to increase dissonance by making the option of eating something or tying out some nutrition more attractive, decrease the attractiveness of eating too little and increase the importance of good nutritional intake.
Req. 33. The system will (as much as possible) show two-sided messages, i.e. also given opposite arguments for advice, but counter these opposite arguments as well.
Req. 34. The system will not have any mention of persuasion or that the goal is to influence the patient.
Req. 35. The system will make clear that the user's choice won't be limited now or in the future.
Req. 36. Development of the system should be done as munch as possible following the guidelines of the "eight step design process" as explained in section 3.3.

Table 4.1: Comparing persuasion theories with requirements

Persuasion theory	Requirement	Specific persuasion element
Stages of change	30	Stages of change
Cognitive dissonance	31 32	Prevent justification for change Increasing dissonance
Eight step design process	36	Eight step design process
Persuasion design principles	21 22 23 24 25 26 27	Tailoring Simulation Praise Social learning, social comparison, social facilitation, cooperation, competition Normative influence Expertise, verifiability Third-party endorsements
Ability, motivation and trigger	28 29	Increasing of motivation Triggers
Persuasive messages theories	33 34 35	Two-sided messages Persuasive intent Prevent loss of personal freedom

4.3.8 Other functionality

Other requirements the system should fulfil are described here. Nurses are always busy and it's impossible to train them using a system solely for this research; their help should not be required for the usage of the system. Another aspect is that patients are often in a room with more patients and the usage of sounds should therefore be prevented.

Req. 37. The system requires no actions from nurses or other hospital staff.
Req. 38. The system will not use sounds (except for the notifications) because the patient is often in a room with other patients.

5 Application design and usability testing

To create a system with the functionality described in chapter 4, there are various options available. This chapter covers the design and testing of this design for the application. In section 5.1 it will be elaborated why an iPad was chosen to develop the application for. Mock-ups of the application have been designed and discussed in section 5.2. The design is tested with users, and the procedure for this usability testing is explained in section 5.3. Section 0 will mention the results of this usability testing and in section 5.5 the consequences of the usability testing for the final design will be discussed.

5.1 Device choice

Although previous sections have mentioned several times that the application will run on a tablet, it will be explained here why that choice has been made. The most ideal situation would be to use the smartphones of the patients. Patients could for example go to a website or download an application. Because of the many possible platforms available, development of an application would take considerable amount of time, and is not feasible. Creating a mobile website where the patient can go to with the browser on the smartphone is also not an option since the hospital has no complete Wi-Fi coverage. Another problem would be that for the group of people aged between 55 and 64 and owning a phone, only 30% has a smartphone. For people of 65 years and older, only 18% has a smartphone as opposed to a more basic feature phone (Nielsen, 2011). Because of the high average age in hospitals, the smartphone penetration in the Aalborg hospital would probably be low. Combined with the difficulties of supporting multiple development platforms and the sometimes absent Wi-Fi connection, it is decided not to use the smartphone of the patient for the application.

Since it is not necessary to use a smartphone, there are other technology options available as well. A laptop is a possibility, but is not very confortable to use when laying in bed. A smartphone has the advantage of being more portable, but has a small screen which can make it difficult for senior people to control. A tablet is the golden mean with portability and the touch-screen is intuitive and easy to control (at least more intuitive and easier than a laptop with a mouse).

Tablets are a rising technology product, with an expected yearly sale of 107,4 million in 2012 which increases to 222 million in 2016. It is expected that the market share of Apple is 62,5% in 2012, while Android has 36,5% and Blackberry and other companies the remaining 1% (IDC, 2012). Because Apple with the iOS platform has the highest usage and there is an iPad available for this research, the application will be developed for an iPad.

5.2 Initial graphical designs

Based on the functionality described in chapter 4, screenshots of the application have been designed. The designs are made in Adobe Photoshop and the application icon in Adobe Illustrator. Standard iPad elements are used from the template created by Teehan+Lax (2012). Using this template has the advantage that usability and design guidelines from Apple – called the iOS Human Interface Guidelines – can be easier applied in the design (Apple Inc., 2012).

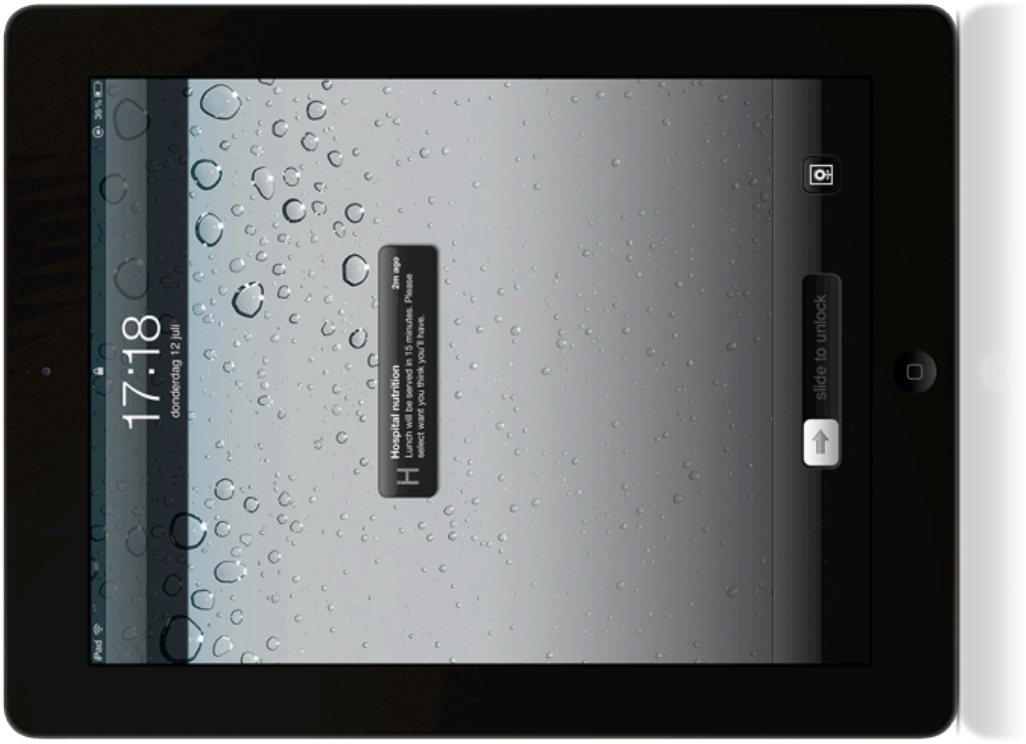

Figure 5.1: Notification before lunch time

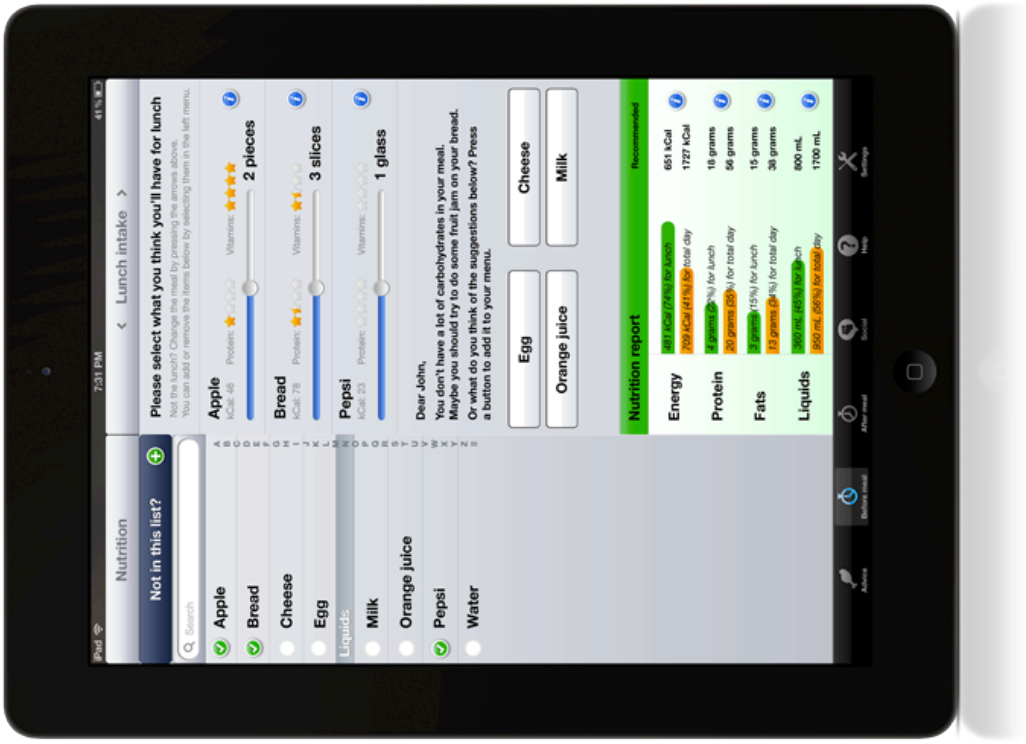

Figure 5.2: Selecting what the patient think he/she will have before the meal

There are no designs made for the demonstration of the application. This is because the demonstration is mostly showing screenshots of the application and explaining its functionality. Because the graphical layout of the final application will probably be different than the designs, it would be pointless to make designs of the demonstration functionality.

For every meal (e.g. breakfast, lunch and dinner), the application will give 15 minutes before a notification. The layout of this is standard iOS behaviour. Figure 5.1 shows an example text for the lunch meal; sliding when the notification is given will result in opening the before meal screen.

The before meal screen is shown in figure 5.2. An important aspect of this screen is that the user should be able to see the result of changing his/her menu choice. Increasing the amount of some food has immediate effect in the nutrition report in the bottom of the screen. Another important – but still difficult to realize – design decision is to have the possible nutrition options (now on the left side) on the same screen as the amount selectors (on the right upper side). This results in a very full screen with lots of elements and has the potential of being unclear to novel users. However, putting the possible nutrition options in e.g. a popover or other screen would possibly result in users not being able to change the choice of menu quickly, and therefore hinder them to try out other nutrition options and see the result of it in their nutrition report. More separate screens and often switching between them could also lead to confusion and decreased user experience because it can take longer to input everything into the system. This is the reason why it is decided to put the nutrition options on the same screen as the amount selectors.

The before meal will also show nutritional suggestions to the user. Finally, for the selected nutrition, a blue information icon is shown. Pressing this button will result in a popover showing nutritional information of this; there is no screenshot of this popover.

30 minutes after the meal, another alert will be given, similar to figure 5.1. Opening it will show the after meal screen (figure 5.3). In this screen the actual amount of consumed nutrition is registered. It looks very similar to the before meal screen, to avoid confusion and make the application easier to learn. The nutritional report is not shown, to prevent that patients would possibly change the amounts in a more preferable way. After all the correct amounts are selected using the slide bars, the user has to press the green button for answering some questions.

The questions (figure 5.4) about the meal is usable information for composing a nutritional advice. Three kinds of questions are asked: the reasons for non- or less consumption, the satisfaction with the food and general remarks. The satisfaction and general remarks cannot be directly used for the advice, but can later turn out to be useful when interpreting these results. Some of the reasons for non- or less consumptions are probably also not very useful for the advice (e.g. the food was cold), but some can be useful (e.g. if the patient indicates having problems swallowing, the advice can be to take a high calorie nutritional drink). To prevent having complicated screens and patients having to spend too much time filling in the form, questions are about the entire meal and not individual nutrition options.

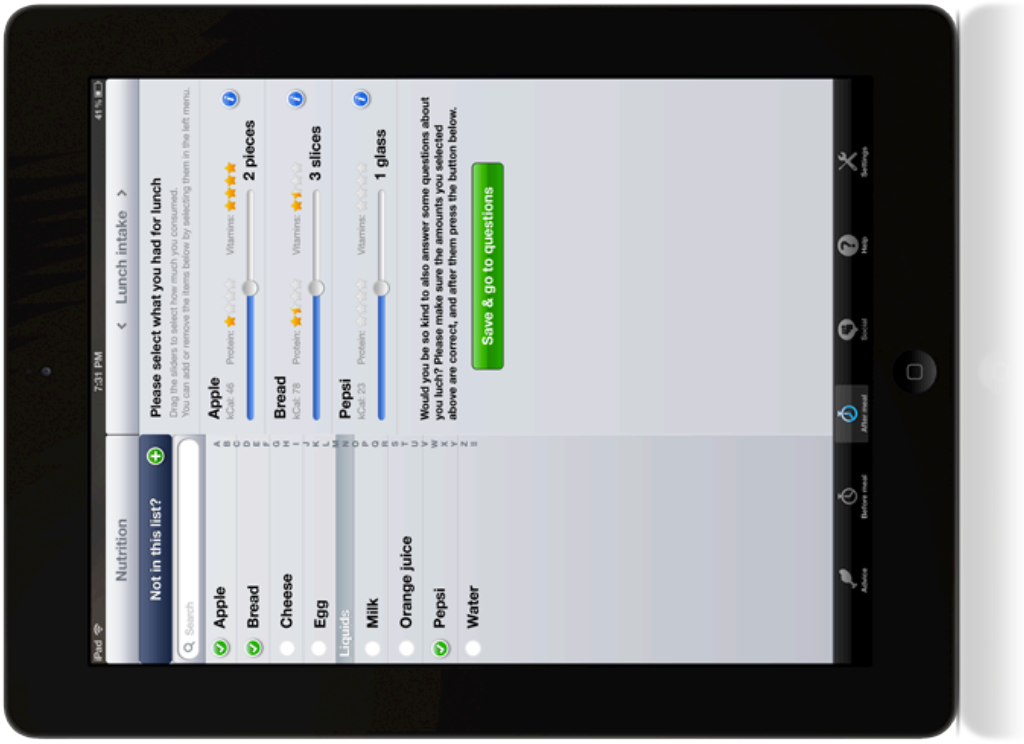

Figure 5.3: After meal screen for registration of consumed nutrition

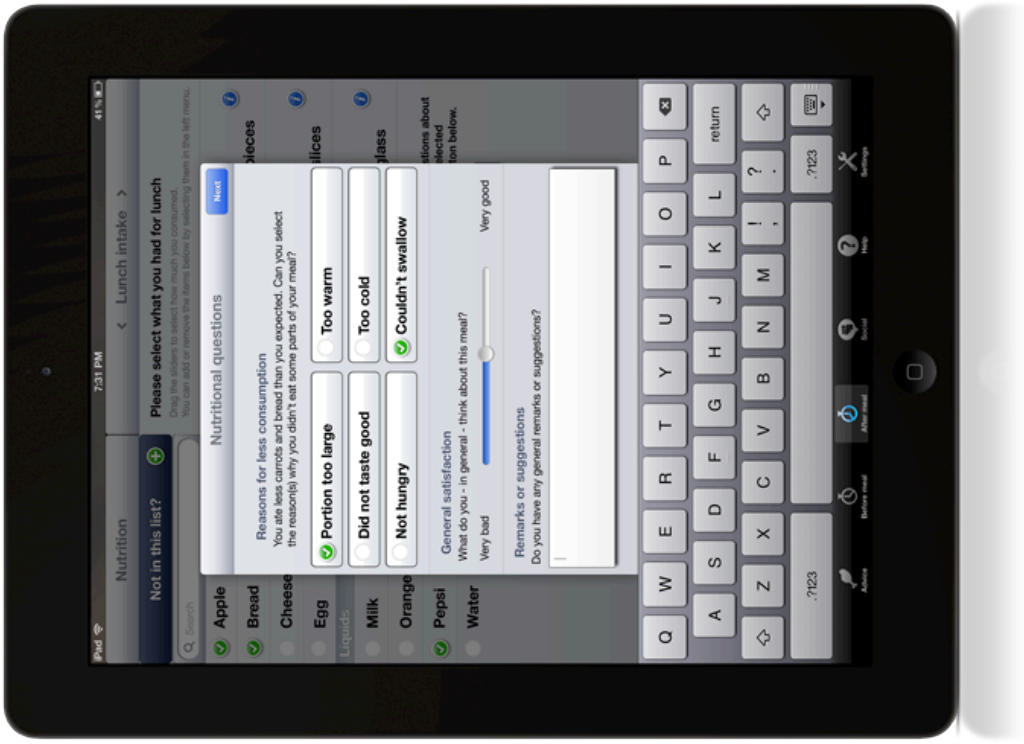

Figure 5.4: Nutritional questions asked about the meal

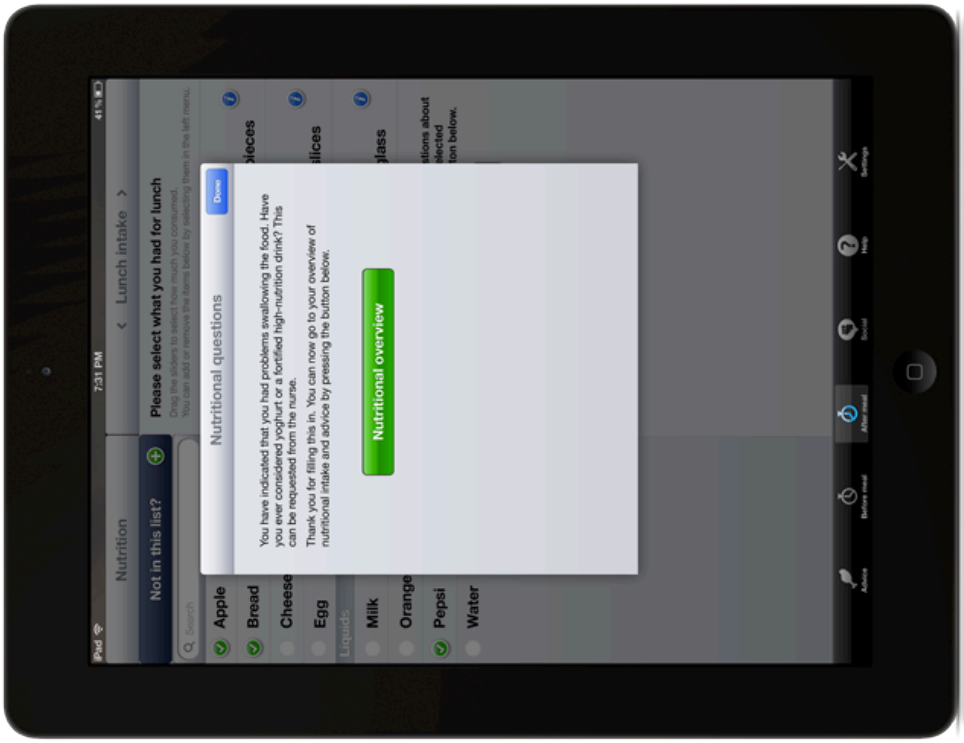

Figure 5.5: Advice given after nutritional questions after meal

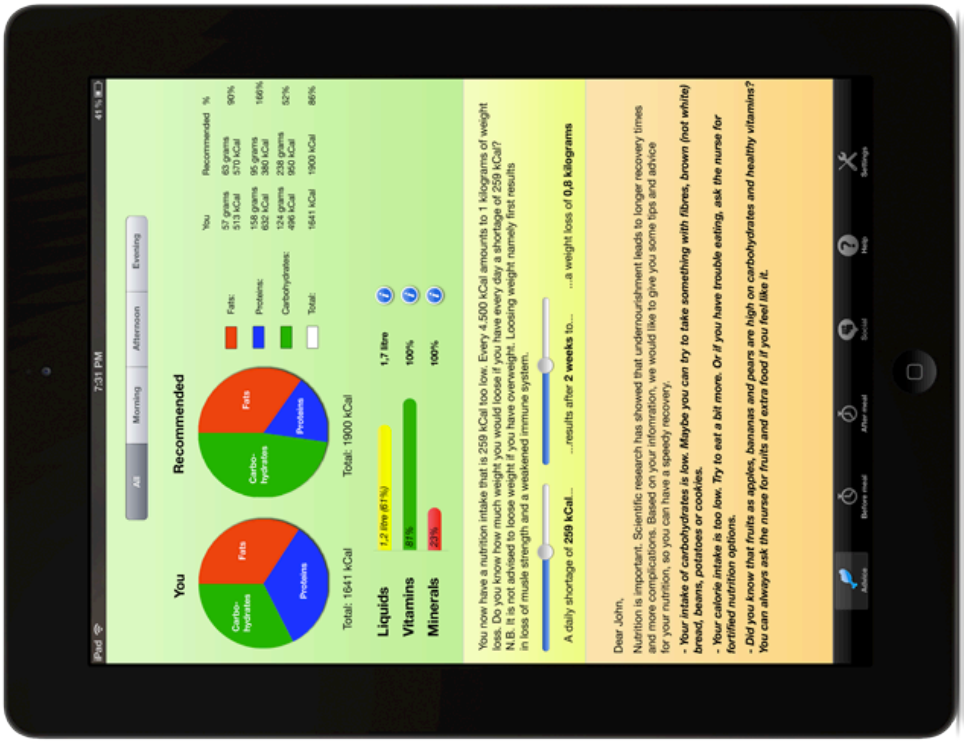

Figure 5.6: Advise screen

After answering questions about the meal, the application will give a small advice for the next meal (figure 5.5). This is done to let the user reflect on choices about the consumed nutrition and have an effect on the next meal selection. The screen has a button to go to the advice screen. The button is called 'nutritional overview; instead of 'advice screen' to give the user of feeling that the advice is extra and the screen is primarily about showing the progression of the patient.

The advice screen is shown in figure 5.6. This screen shows the nutritional intake of the patient (on top), tries to make the patient aware of the consequences of undernourishment (middle) and gives advice (bottom). To keep things simple – both for the user and the implementation of the application – the intention is to have all advice elements on one screen. The nutritional intake is shown with a pie chart, with the intake from the patient compared to the advised amount. This gives a clear overview of how the energy intake of the patient is subdivided, but for more detail there is a table to show the specifics. Nutritional elements that have nothing to do with energy (i.e. liquids, vitamins and minerals) are shown in a bar to give a good overview of how close the user is to the recommendation. A distinction is made between morning, afternoon and evening, or all can be selected at once; selecting one will result in immediate changes in the charts and table.

The centre of the screen shows the loss of weight when continuing in this rate of nutritional intake. The user can try out different periods and calorie values, which will give the user more insight into the consequences of undernourishment. The input method of sliders has been chosen, to make it easy and see immediately the effect when changing values. The advice in the bottom of the screen is textual. Although it's less appealing to read a lot of text, no better way has been found.

There is some social functionality in the application. The problem is that because there is only one iPad during testing, it is impossible that a social community will arise. Therefore, the messages from this community will be faked. Users will get an impression of the possibilities and can respond to it in the debriefing. To make clear that the messages are not from real users, abstract profile images are used. These profile images originate from Icons-Land (2012). Because the priority of the application will be on nutritional intake, this social functionality will not be made dynamic (e.g. a personalized profile page on which other users can write messages), since that will take too much development time. The screens will be in the application to give the users an impression, not a complete social platform.

In figure 5.7 the first social screen is shown, which will display the (fictive) messages. To keep the layout simple and comparable to the nutritional intake, a two-column layout has been used. The user has the possibility to see more information about a person by pressing on a name in the left side, or by pressing on a blue button with an arrow. This will show a screen like figure 5.8 with information about a particular person. The information in this screen is limited to see a chart with energy values and compare it to the user's own performance. The user also has the ability to write a message to the (fictive) person. It is possible to go back to the messages screen by pressing the back button in the top, which is standard iOS behaviour.

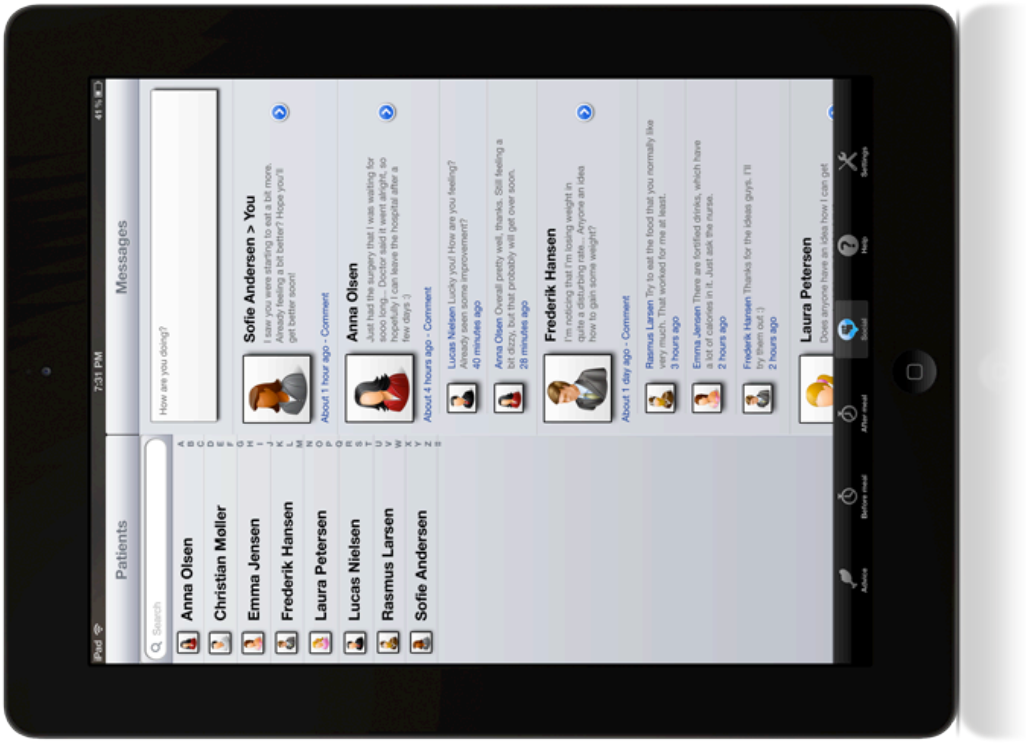

Figure 5.7: Social screen with messages from users

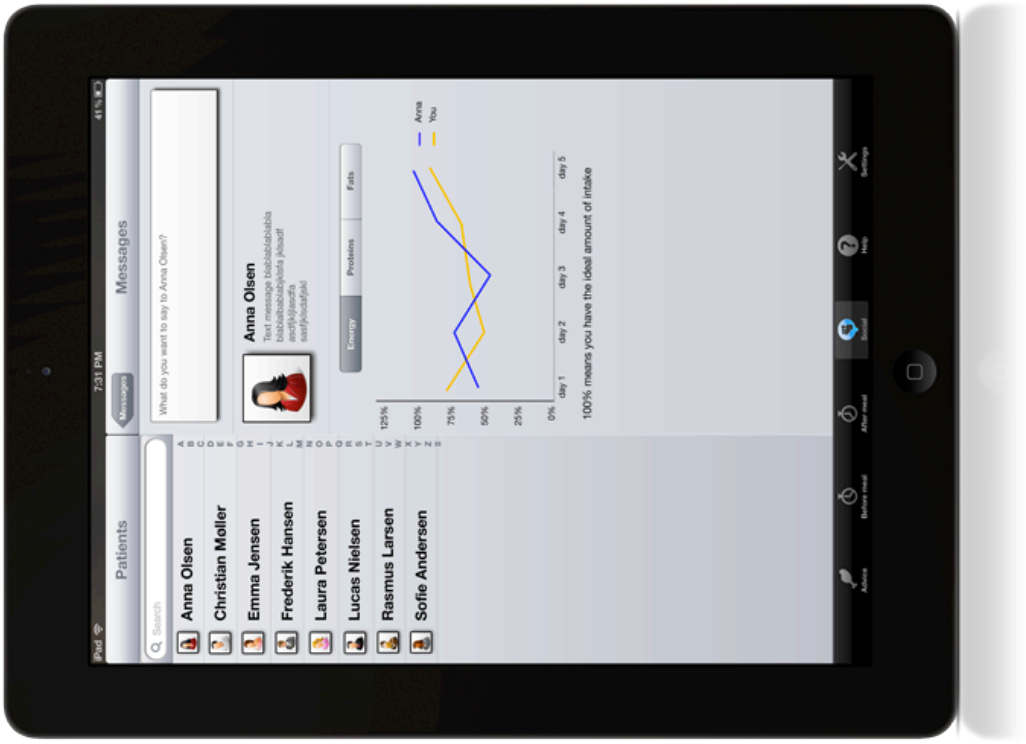

Figure 5.8: Social screen with information from a particular user

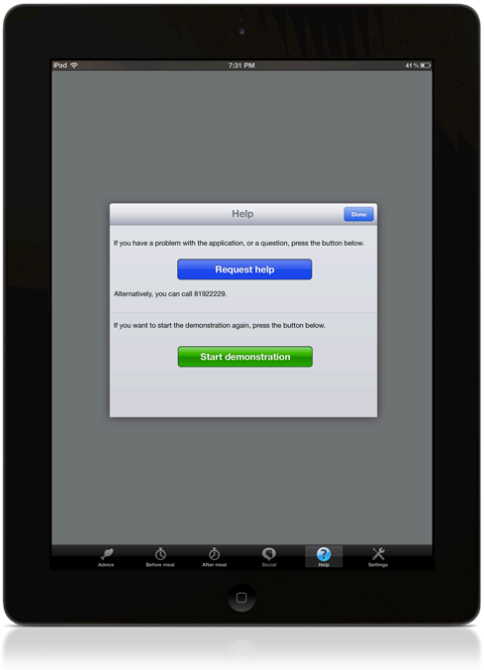

Figure 5.9: Help screen

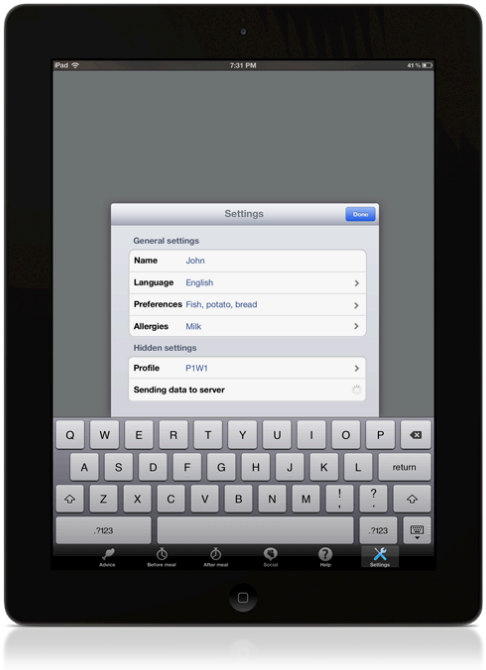

Figure 5.10: Settings screen

The last two screens are a help screen and a settings screen. The help screen (figure 5.9) has two functionalities. First it shows contact information and offers the option to automatically contact the researcher (blue button). This is useful when the patient has a problem and doesn't know what to do; instead of that the day after it turns out that the patient didn't use the application, assistance can be provided. The second functionality is that the demonstration can be started again (the green button).

The settings screen (figure 5.10) does not have many options. The patient can change the name, language, preferences and allergies. The preferences and allergies are used to formulate an advice. There are options only available to the researcher, namely to change the profile (or create one) and sending data to an external server.

5.3 Usability testing

Before using the application in the hospital with patients, it is important to have as few usability and design errors as possible. The experiment described in section 7.5 can only be executed once; changing the application during the testing on patients could alter the results and is therefore not possible. Time wise, it is also sensible to prevent design errors to creep in to the implementation, since fixing this after the implementation has been completed would take more time. The designs presented in the previous section are therefore tested on usability issues.

This usability testing is also in line with the iteration and prototyping paradigm suggested by Dix, Finlay, Abowd, & Beale (2004, p. 220). This checking of (possibly paper-based) prototypes "whether they are acceptable and where there is room for improvement" can go on until there are "no more problems

that can economically be fixed". For this project there is only time for one iteration of usability testing.

A problem with summative usability studies is that the system is judged based on predefined performance goals. Setting these goals beforehand is difficult and achieving the goals may not necessarily mean that the final system has high usability. Usability metrics "rely on measurements of very specific user actions in very specific situations". In the early stages of design, the designer does not know yet which actions and situations there will be (Dix, Finlay, Abowd, & Beale, 2004, p. 241). This usability testing will therefore be formative, and focus more on qualitative information (e.g. users' ideas about improvements) than measuring e.g. efficiency, effectiveness and satisfaction levels.

The usability testing is done in a Wizard-of-Oz simulation where the designs of section 5.2 are used as a paper-prototype to simulate the application. Participants of the usability study should generally be as close as possible to the target group of the application. However, it's not possible to test the design on patients of the hospital, and therefore healthy people are used. Since the persuasion elements target hospital patients with their specific behaviour, persuasion is not part of this usability testing. The target group of the application is very broad, so there are no specific conditions for the testing participants only that it is generalized and non-specific. The well-known article of Nielsen and Landauer (1993) shows that after five users the number of usability problems found decreases considerable. They also estimate that the optimal number of users for user testing in a small project would be seven. Although it has to be mentioned that this static number of users is controversial (Lewis, 2001), and some more difficult approaches have been proposed (Woolrych & Cockton, 2001).

First, all participants have to sign a consent form, which states that they give informed consent to the usability testing. The consent form also serves as a standardized way of explaining the usability test. Therefore it will give some background information about the research, where and how the application is going to be used and explains the procedure. The consent form is based on the template from the User Experience Group of Indiana University (2005) and can be found in appendix A.1.

Second, the participants in the usability testing do a walkthrough, which means that they go through the (simulated) system by doing some tasks. These tasks should of course not be too specific (e.g. press the green button) because that would contradict the goal of the testing, which is finding unclear or problematic design issues. The users' actions are video recorded and users are asked to think aloud. Thinking aloud has the advantage of getting insight into the reasons why users do certain actions, and can be the basis for questions after the tasks (Dix, Finlay, Abowd, & Beale, 2004, p. 343-347).

There are three tasks the participants have to do. The time it takes the user to complete this task is measured. If the user cannot succeed, a hint will be given, but this is mentioned in the results. The three tasks are:

- 15 minutes before lunch you receive a notification (figure 5.1); open it and enter that you would like to have two slices of bread and 2 pancakes.

- After lunch you have to fill in what you ate and drank (figure 5.3). Select something, answer the questions (figure 5.4) and go to the nutritional overview (figure 5.6).
- Go to the social section (figure 5.7) and visit Anna's profile (figure 5.8).

Third, to obtain some general information and impressions of the user, a small questionnaire will be held. Usability questions have a five-point scale and two questions are open-ended. The questionnaire is based on the Standardized Computer System Usability Questionnaire at IBM (Lewis, 1995). This survey is also recommended by Lazar, Feng, & Hochheiser (2010) as one of the recommended tools for usability testing and evaluation. However, seven questions (about completion of work, productiveness, error messages and documentation) not related to the application under observation were removed. The questionnaire also includes questions about the age, gender, experience with tablets and hospital visits of the user. The complete questionnaire can be found in appendix A.2.

As has been mentioned, the focus of this usability testing will be on qualitative information. The fourth and last part of the usability testing is therefore a semi-structured interview with questions related to the observation. This interview is done after the questionnaire, to prevent biased responses (Brooke, 1996). The thinking aloud and other remarks made by the participants – in combination with this interview – will be used to help clarifying reasons why users behave or think a certain way (Dix, Finlay, Abowd, & Beale, 2004, p. 348).

5.4 Results of usability testing

Seven people were found prepared to participate in the usability testing. As mentioned in the previous section, these were all healthy people and were currently not hospitalized. Unfortunately someone stopped during the testing; testing results from this person are therefore not used. The remaining six participants all completed the three tasks and questionnaire as described in section 5.3. Of the six users were three male and three female and two were not experienced with a tablet while two were very experienced. Half of the participants never stayed in the hospital, two stayed only a few days and one user stayed a week.

Table 5.1 shows the success rates of the three given tasks. A task is considered as failed when a hint had to be given or when the maximum time of 90 seconds was exceeded.

Table 5.1: Successfulness of usability tasks

	Task 1	Task 2	Task 3
User 1	Yes	Yes	Yes
User 2	No, a hint was given for adding a nutrition option	Yes	Yes
User 3	No, a hint was given for adding a nutrition option	No, a hint was given for the button "Next" in the questions screen (see figure 5.4)	Yes
User 4	No, a hint was given for adding a nutrition option	Yes	Yes
User 5	Yes	Yes	Yes
User 6	No, the user did not complete this task and continued to the next	Yes	No, a hint was given about the bar at the bottom of the screen

In general it was confusing that the before meal screen had already three nutrition options selected when the user started the testing (see figure 5.2). A separate screenshot with no nutrition options selected would probably have resulted in less confusion.

Adding a new nutrition item was by far the most difficult (sub)task. Pancakes weren't an option in the nutrition list and had to be added to the list. The add button for this was above the list but apparently users overlooked it. User 1 found it after a while, users 2, 3 and 4 didn't see it and had to be given a hint.

The results of the questionnaire can be found in appendix A.3. Overall users were quite positive and gave fairly high grades. Since only six participants filled in the questionnaire, no statistical analysis has been performed. Five out of six found it fairly easy to use the system, and the same number found it fairly easy to learn to use the system. Half of the people found the information provided with the system fairly easy to understand, one found it very easy to understand, one was neutral and one found it a bit difficult; this was to most negatively answered question. Five out of six were of opinion that the interface of the system is fairly pleasant and five people fairly liked the interface. Overall, five users were fairly satisfied with the system with the remaining one answered to be very satisfied.

Remarks made by the users (among others) were about the difficulties to finding the pancakes, the use of icons in the nutrition list and the suggestion to add news and weather forecasts. Positive remarks were about the lay-out and simplicity of the design. Negative aspects were the lack of a back-button and the suggestion of more interaction in the sense that information on the screen should depend on the given input.

After the questionnaire and sometimes during the testing, open questions were asked to the users about their experiences or problems they had. Users made the following remarks:

1. User 2 remarked that in the popover screen in the after meal questions there are two buttons to exit: a done button and a green button (see figure 5.5). User 6 also made this remark and suggested to remove the additional green button in the popover because it is confusing.
2. User 2 suggested that the after meal screen should by default show the options already selected in the before meal screen.
3. User 3 suggested that in the list with nutrition options pictures could be added. That could make the different nutrition options clearer.
4. User 3 made the remark that it is possible that patients receive food from family members that are visiting, and the system should take into account that other food options not provided by the hospital can be consumed.
5. User 4 was more familiar with the Android operating system and said that an add button (for in the nutritional list) would be in Android in the bottom of the screen instead of in the top.
6. User 5 wanted to go back after seeing the advice screen and was therefore missing a back button.
7. User 6 suggested to start the sliders at 0 instead of half way.

5.5 Improvements in design

The usability testing has been used to make improvements to the design of the application. No new screenshots have been made, but the feedback has immediately been incorporated into the implemented application. Screenshots of this final application can be found in the next chapter, chapter 6.

As has been remarked in section 0, some usability problems were caused by testing it on paper. There were only limited screenshots available, and some screens were dependent on the actions of the users (e.g. the before and after meal screen showing the selected nutrition options).

The list below mentions changes because of the usability testing, or reasons are given for not changing something. Numbering refers to the numbered list in the previous section 5.4.

1. In the popover screen with the after meal questions, the green button has been removed because that was considered confusing.
2. When nutrition options have been selected in the before meal screen, they will by default also be added to the after meal screen. Except when options are already selected in the after meal screen, they will in that case not be overwritten.
3. Showing pictures of all nutrition options is not feasible. There are too many nutrition options and taking pictures of all the food and drinks in the hospital is too much work. External picture databases cannot be used since that nutrition can look (slightly) different than that provided in the hospital, which can cause confusion.
4. Other nutrition provided by e.g. family members can be added to the nutrition list. Nutritional values (e.g. energy, protein, vitamins) are

unknown, but letting the user fill this in is probably also impractical since the user doesn't know these values.

5. Although the button for adding nutrition options wasn't clear, a better solution was not found. Showing it in the bottom of the screen instead of the top (as suggested by a user) caused problems with scrolling through the nutrition list. It has been decided to stick to Apple's iOS Human Interface Guidelines and put the button in the top with the title of the nutrition list (Apple Inc., 2012).
6. Because the application uses pages –which can be opened from the bar in the bottom of the screen – there is no back button. There is also no real starting page; users can open any of the pages and go through them in any order. A back button would suggest a logical order in this and since there is no correct way in the order of opening the pages, no back button has been added.
7. The remark to starting the sliders at 0 instead of halfway was probably also related to the fact that nutrition options were pre-selected in the screenshots used for the usability testing. The user found it namely annoying to put the sliders back to 0. In the final application no nutrition options are by default selected. The remark did trigger a thinking process about what would be a good starting value for the slider. It was decided that the slider starts at an amount which would be most likely for the patient to have, e.g. 1 portion, 1 glass or 1 teaspoon (depending on the product). The user can then select less (slide to the left) or more (slide to the right), which seemed the most logical way to select an amount.

6 Application implementation

This chapter will discuss details about and the process to the final implementation of the application. Implementation started with getting a list of nutrition options, which is elaborated in section 6.1. During development of the application, various meetings have taken place with employees from the hospital, which led to the valuable feedback in section 6.2 and the system giving a correct nutritional advice (section 6.3). A bit more to the end of the implementation the entire application was translated to Danish while keeping English still available, as explained in section 6.4. Section 6.5 elaborates on the bit cumbersome process of getting data out of the program to use it for analysis. More (technical) information about the application – including a database model – can be found in section 6.6. The preliminary application has been tried out with a patient in the hospital, which led to many improvement points (section 6.7). The final application with screenshots can be found in section 6.8. The last section 6.9 compares the functionality of the final application to the initial requirements.

6.1 Nutritional options

The application has to be able to display the nutrition options available in the hospital. A list with the food and drink options has been provided by the hospital. Next step was to be able to know what the nutritional values (e.g. kcal, proteins, fats, vitamins) of these products are. For this, the database of www.foodcomp.dk has been used (Saxholt, Christensen, Møller, Hartkopp, Hess Ygil, & Hels, 2009). This database contains 1049 items and is especially suitable because it contains data of Danish nutrition. International food databases are for this research worthless since the hospital menu contains e.g. minimælk, havregryn, øllebrød or frugtgrød. The database is downloaded in an ASCII file and with self written software in the language PHP converted to Objective-C syntax to be able to import it in the application database. For the conversion of kJ to kcal a value of 4,1868 has been used as defined in 1956 by the Fifth International Conference on the Properties of Steam (National Institute of Standards and Technology, 2008).

The information from the foodcomp.dk database is for all products per 100 grams. In the application however the amounts are selected for one measurement unit. This measurement unit can be: piece, slice, glass, plate, portion, tablespoon, teaspoon, bottle or cup. The amount for one measurement unit (e.g. portion) differs per nutrition option; one portion of salad doesn't weigh the same as one portion of pasta. For this a list with the weight of average portions (or other measurement units) for nutrition has been used (Andersen, Jensen, & Haraldsdóttir, 1996). Some specific food items, for example the energy dense nutrition drinks, were looked up on the Internet at the producer's website for the nutritional values and weight.

After implementing this, the nutrition list in the application was checked with a dietitian from the Aalborg hospital. It became clear that there were some anomalies in the data. For example, glasses in the hospital were 150 mL instead of 200 mL and for one portion of cornflakes the application indicated it would be 850 kcal (which is almost twice as much as a normal meal). In the case of

cornflakes the problem was caused by the article of Andersen, Jensen, & Haraldsdóttir (1996) indicating a portion size of 200 grams, while that was with milk and the nutritional values of foodcomp.dk showed the cornflakes without milk. Changing the portion to 30 grams and indicating that this is without milk solved the problem. Similar discrepancies were manually traced and resolved (e.g. with havregryn and müsli).

To prevent other errors to creep in, all the food and drinks available in the main kitchen in the hospital were weighed. If the value deviated from the weight used in the application, the weight of the weighing scale was used. If the value from the weighing scale was close to the value already in use, it was not altered since the weighing in the article of Andersen, Jensen, & Haraldsdóttir (1996) was done more accurately.

As will be elaborated more in section 7.1, parts of the lunch and the complete dinner changes daily. Personnel from the main kitchen in Aalborg hospital is responsible for the menu, which is composed with much care to comply with Danish regulations about hospital nutrition. Interviews gave insight into this process and how information was saved in the computer system. The researcher was granted access to all available data from this "MasterCater" system. In MasterCater information about the lunch and dinner menus is saved, including the weight of one portion and nutritional values (e.g. energy, protein, vitamins). Unfortunately MasterCater has no option of exporting data, and therefore for every day the nutritional data of every menu option has to be entered in the application manually.

6.2 Consulting with dietitians

Because the application uses nutritional information to provide advice, it makes sense to check the application on omissions and faults. The head of clinical dietitians and head of clinical nutrition research of Aalborg hospital were involved to analyse the system. In several meetings the general functionality of the application was discussed and evaluated. The most important changes made to the system because of consultations with them were:

- Focus has been especially shifted towards the intake of protein. With hospital patients, proteins are really important and it is rare that a patient gets enough. Most advices focus on this, and when selecting the amount of nutrition the stars to indicate the level of vitamins (see figure 5.2 or figure 5.3) have been replaced to show the amount of proteins in grams.
- The BMI bar on the advice screen was slightly changed. The lower limit of good/underweight is normally 18,5 but was changed to 20,0 to indicate that patients in the hospital who are already in the lower regions of BMI are considered underweight when being a patient. For patients with the age of 70 or older the upper limit for having normal weight was increased and the category severely overweight was removed; older patients tend weigh a bit more which is healthy. See figure 6.1 and figure 6.2.

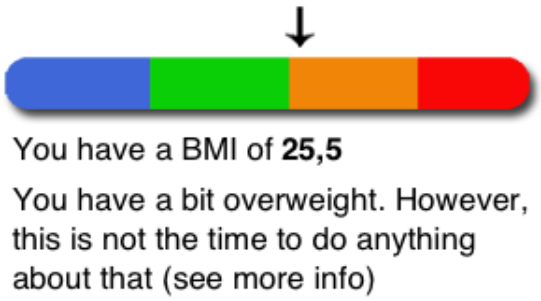

Figure 6.1: BMI bar in advice screen for person under 70 years

Figure 6.2: BMI bar in advice screen for person of 70 years or older

- The questions asked to the user after inserting the amount of consumed nutrition were evaluated and formulated. Questions were split up in three answer categories: food quality, patient and surroundings. Although food quality answers can't be used in the advice for the user (since e.g. the food being too warm or cold can't be changed) it might give interesting results about the quality of the food. Other answers are used in the advice generation, as explained in the next section 6.3.
- In the advice screen it is possible to see detailed statistics about the intake and recommended nutritional values. Another column has been added with the planned (before the meal) intake. This makes it possible for the user to be able to plan multiple meals for the entire day.
- Since both persons were scientifically educated, the significance of numbers was questioned. Digits after the decimal separator were removed (with the number being rounded) or limited to one number after the comma.
- Instead of that the user has to enter what he has consumed, he can take a picture and upload this. A dietitian would then judge the amounts and nutritional values. Because there was no Wi-Fi access for an iPad possible in the hospital, this functionality was not further expanded. With Internet available an option would be that the dietitian could remotely input the nutritional data in the application.
- In the nutrition list a categorization was implemented. The list became long and nutrition options were difficult to find, and therefore a categorization of meals (e.g. breakfast, lunch) was created with in that category a secondary ordering based on name.

6.3 Advice and recommendations in application

With the two persons from Aalborg hospital (introduced in the previous section 6.2) it was decided to focus primarily on protein intake. It is hard to make an individualized advice, because that is already difficult for dietitians to do. Incorporating allergies and preferences of the user in the advice would make the application severely more difficult to implement and is therefore not done. It has also been discussed to base the advices primarily on patients with nutritional risk, since the application would be most beneficial for this group. Other patients can still use the application although the advices are maybe a bit less useful.

There are two points in the application where advices are given. First is in the before meal screen where products are recommended to include in the meal. Depending on which meal is selected (e.g. lunch, dinner) four options from the nutrition list are displayed. When the selected nutrition is really low on proteins, the four options will display products with high protein values. When the selected nutrition has some proteins but still insufficient, the four options will display products with above average protein values. And also when the user has selected sufficient protein in his meal, the four options will still show above average protein products because more protein is only good for a hospital patient.

The second advice is a textual advice in the "advice screen" of the application. A general text about nutrition and hospital patients is always displayed, and further advice depends on answers given in the questionnaire in the after meal screen. For example, with swallowing and chewing problems an advice about alternative food is displayed, while if the user would answer with nausea or pain an advice about possible medication is showed. For when the user haven't filled in the questionnaire yet and to also show other advice texts, nine general advice texts are created. The specific texts being displayed in the application is random, with a higher chance for certain advice texts when certain answers are given in the questionnaire. All advice texts are written in cooperation with the two employees from Aalborg hospital to make sure the advices are correct.

Besides the recommended products and textual advice, there is also an overview of planned or consumed nutrition. There are statistics about a comparison of planned and consumed nutrition to recommended values. Specifics about the ideal (recommended) amount of energy and protein intake are explained in the next chapter, section 7.3. Besides the kcal and grams of proteins, there are a lot more nutritional values being registered by the application. All recommended values in the bullets below are for a day; for a specific meal they are multiplied with a factor. This factor is 0,2 for breakfast, 0,2 for lunch, 0,25 for dinner, 0,1 for the first in-between meal, 0,15 for the second in-between meal and 0,1 for the last in-between meal, which in total sums up to 100% for the entire day. Recommended values originate from the source Ministeriet for Fødevarer, Landbrug og Fiskeri (2009).

- Fat is 40% of the energy intake. The amount of grams can be calculated by dividing it by 9 since fat contains 9 calories per gram.
- Carbohydrate is 42% of the energy intake and contains 4 calories per gram.
- Total fluids recommended for a patient is highly dependent on the personal situation of the patient (see section 7.3), but for the application an average is taken of 35mL per kilogram of weight.
- Calcium: 800,0 mg
- Cholesterol: 300,0 mg
- Iodine: 150,0 µg
- Iron: 9,0 mg
- Magnesium: 350,0 mg for male, 280,0 mg for female
- Phosphorus: 600,0 mg
- Potassium: 3500,0 mg for male, 3100,0 mg for female

- Selenium: 50,0 µg for male, 40,0 µg for female
- Zinc: 9,0 mg for male, 7,0 mg for female
- Folates: 300,0 µg
- Vitamin A: 900,0 RE for male, 700,0 RE for female
- Vitamin B1: 1,2 mg
- Vitamin B2: 1,2 mg
- Vitamin B6: 1,6 mg for male, 1,3 mg for female younger than 30, 1,2 mg for female of 30 and older
- Vitamin B12: 2,0 µg
- Vitamin C: 75,0 mg
- Vitamin D: 7,5 µg for persons younger than 60, 10,0 µg for persons of 60 and older
- Vitamin E: 10,0 α-TE for male, 8,0 α-TE for female
- Vitamin K: 120,0 µg for male, 90,0 µg for female

6.4 Localization

One of the requirements was that the application should be in English as well as in Danish. All messages generated in the Objective-C code are available in these two languages. The graphical interface was designed in Interface Builder of Xcode (the development environment for Objective-C applications) in English. The program ibtool (part of Xcode) was used to extract texts from the graphical interface, which were translated to Danish and with ibtool again inserted into the Danish copy of the graphical interface. Because some Danish text were longer than their English equivalent, small changes to the graphical interface had to be made.

Since Danish is not mastered by the researcher, all Danish texts were also checked for grammatical errors by native Danish speakers. Parts of the graphical interface were split up and (double) checked by in total five (non-medical) Danes, two people checked messages generated from the Objective-C code and three people checked the demonstration texts. The questionnaire given at the end of the user test (see section 7.6) was checked by three people, all working in the hospital to assure correctness of medical terms and writing style (i.e. using a friendly though clear tone). Advice texts used in the application were made in cooperation with dietitians from the hospital (see previous section 6.3) in Danish and afterwards translated to English by the researcher.

6.5 Data for results

The application contains a “secret” screen with hidden settings, which can be unlocked by certain swipe movements. This makes it possible to change the profile name (every testing patient has a unique profile name) and sending the database to an external server. The database of iOS applications is standard a SQLite database, which is only one file, and this file is sent to the server over a secure HTTPS connection. The file is inaccessible for the general public to download.

This raw data had to be made accessible to be able to analyse it for this research. The SQLite database file can be read with the program *SQLite database browser* (available via http://sourceforge.net/projects/sqlitebrowser/), which can

export it to SQL format. This SQL file is read by an own program written in PHP that imports everything in a MySQL database. Another PHP program can then use the information in the MySQL database to make the necessary calculations and display that in a table. This table is cut-and-paste in Microsoft Excel to make further statistic analysis and chart generation possible. For results of this, see section 8.2. The entire process seems laborious, but there is no way to copy the statistics already generated by the iOS application and send it somewhere.

6.6 Application specifics

The implementation of the application has been done in a timespan of around 6 weeks fulltime (around 40 hours a week). The program CLOC (http://cloc.sourceforge.net/) has been used to count the lines of code of the application. In total there are 39 Objective-C header files and 37 Objective-C implementation files. These have 1147 lines of comment and 5994 lines of code (excluding the 8039 lines of code for filling the database with nutritional information).

The application has 171 images, of which half (85) are doubles for supporting higher resolution iPads. The graphical interface is mainly built in one storyboard with 38 so called scenes (i.e. views). The demonstration has also its own storyboard file and three “xib” files are created for the cell of selecting the amount of nutrition. The application supports iOS version 5.1 and later.

The database of the application consists of five entities (i.e. tables). Figure 6.3 shows the database model of the application. The Nutrition entity has 32 attributes, of which the nutrition name (in English and Danish), energy, proteins, fats, originating database id, (sub)category, portion size and name, 8 kinds of minerals, 10 kinds of vitamins and other nutritional values. When the user has selected he was planning or has consumed something, this is saved in the Consumption entity. The Consumption entity contains the attributes amount, whether it is before or after meal, the meal number (e.g. breakfast, lunch), profile name (unique name of the testing patient) and nutrition reference. All user actions are logged in the Log entity, which saves the time, profile name and log message. Question responses in the after meal screen are saved in the Questions entity with an attribute for all questions (as a boolean), the meal number, profile name, satisfaction rate and remarks. Last entity is the Settings with simply a key and value as attributes. The keys are notification times for meals, information about all users/profiles (name, weight, height, age, fever, bedridden and gender) and current profile in use.

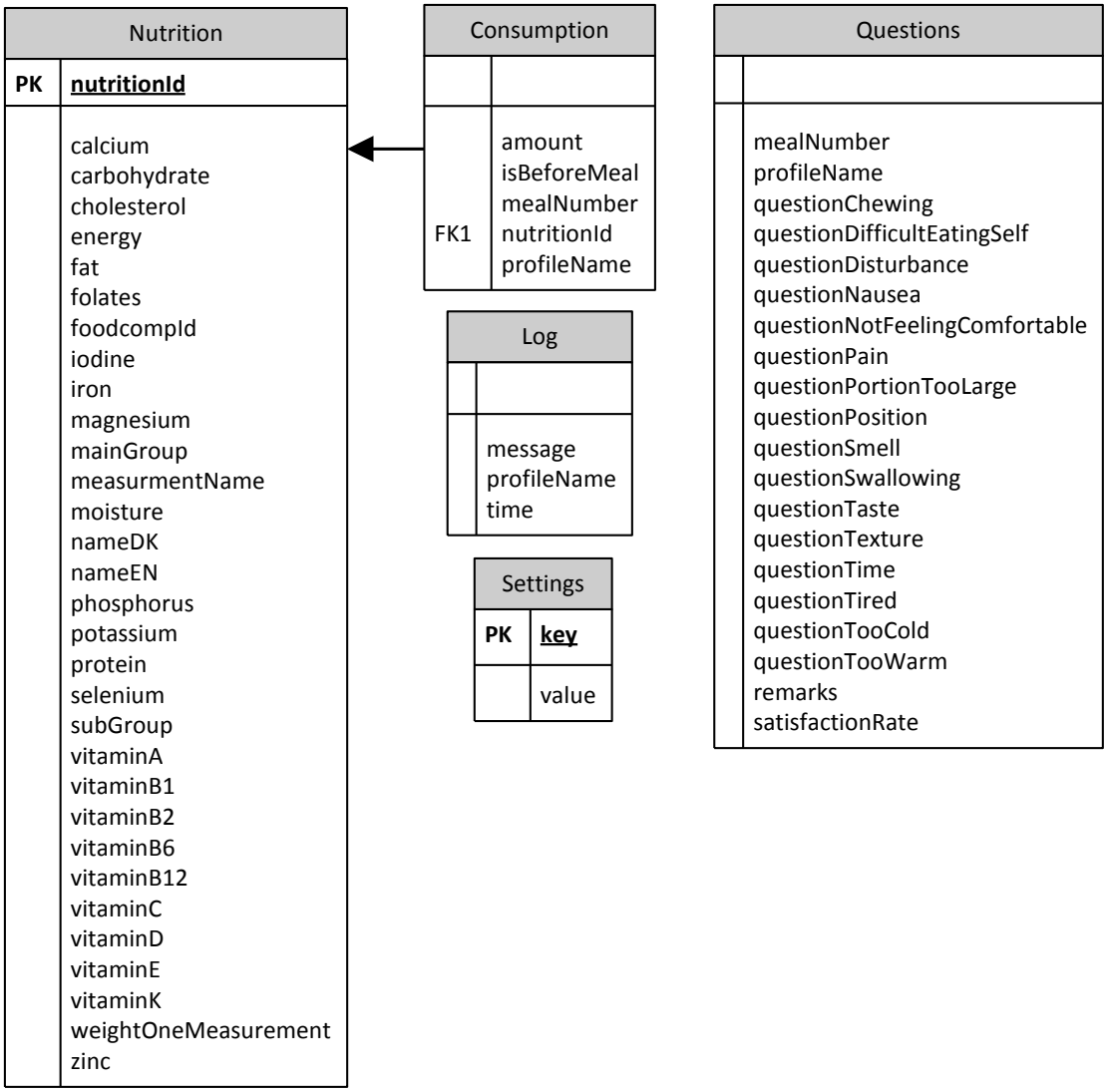

Figure 6.3: Database model of the application. PK stands for Primary Key and FK for Foreign Key.

6.7 First hospital patient

The next chapter, chapter 7, will describe the complete procedure for testing the application with hospital patients and chapter 8 will describe the results of this testing. However, before the actual testing, the application was tried out with one patient in the hospital to discover any problems. This was the last possibility to make changes to the application before it was finalized, since changes made during the experiment can lead to differences in results.

This first patient testing out the application went through the testing procedure described in sections 7.5 to 7.7. Observations, a small interview and the questionnaire led to some improvement points, which were implemented in the application. The testing results of this first testing patient are not taken into account for the results described in chapter 8.

In total 10 issues were found and fixed in the application. The most important of these are: in the nutritional list some options were hidden, the slider for selecting the amount of nutrition was made less sensitive, a save button in the after meal screen was added, sounds of some alerts were turned off, behaviour of

buttons that open a popover changed and a bug of converting kJ to kcal for carbohydrate levels was fixed. The complete list with changes and reasoning can be found in appendix A.4.

6.8 Screenshots

This section will show some of the screenshots of the finalized application. Most design changes after the Photoshop designs presented in section 5.2 have been explained above; other changes compared to the final application screenshots will be explained in this section.

Figure 6.4 displays the advice screen. This has changed a lot compared to the Photoshop design in figure 5.6. The colour background didn't look very nice and the division in three equal parts made it cumbersome to read everything. All elements are in the finalized screen still available. In the top is the advice text because that is the most important. Tips are showed with a checkmark icon and more tips can be shown by scrolling down in that part. Statistics are shown with a pie chart, but to save space the legend has been removed and details of specific meals has been moved to a separate popup screen (see figure 6.5). The weight loss sliders are kept (although that part of the screen is built up more vertically instead of horizontally) and combined with a BMI calculator. BMI calculators are normally intended to show that someone is overweight and he should change that; the goal of this BMI calculator however is to let underweight patients gain weight and make clear for overweight patients that this is not the right time to lose weight (see figure 6.6).

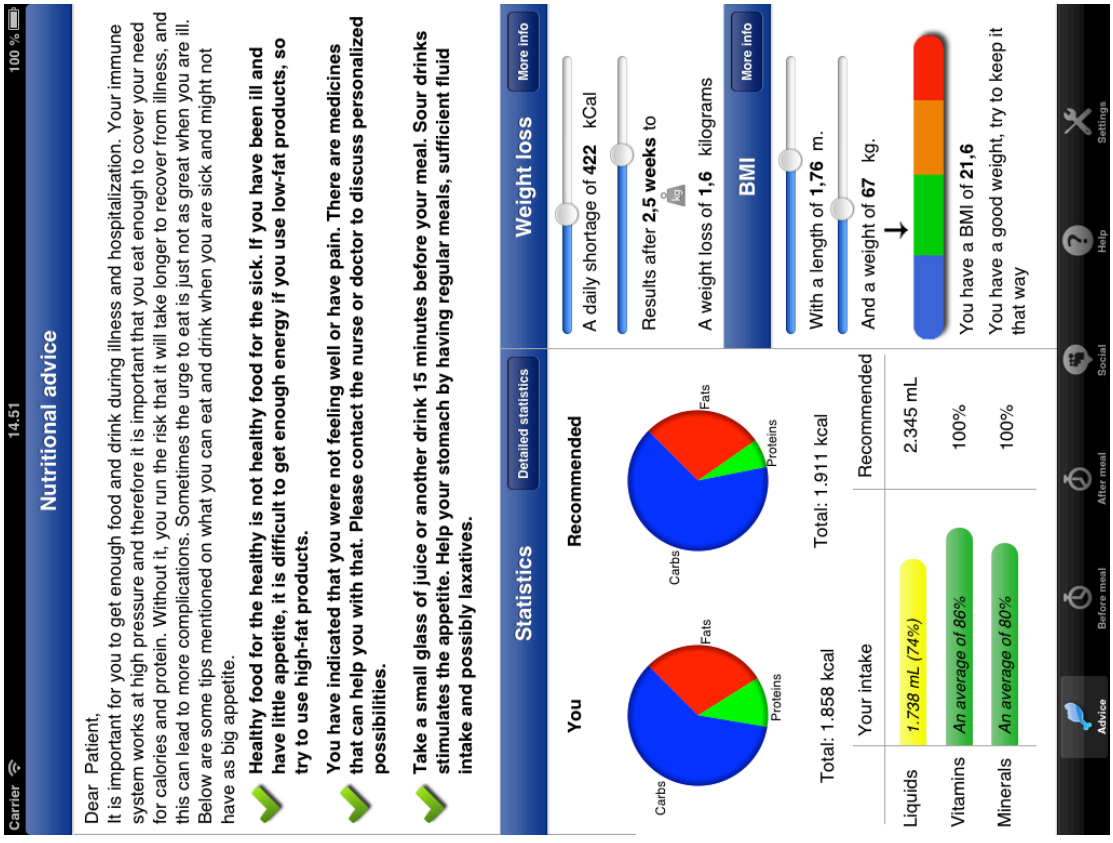

Figure 6.4: Advice screen

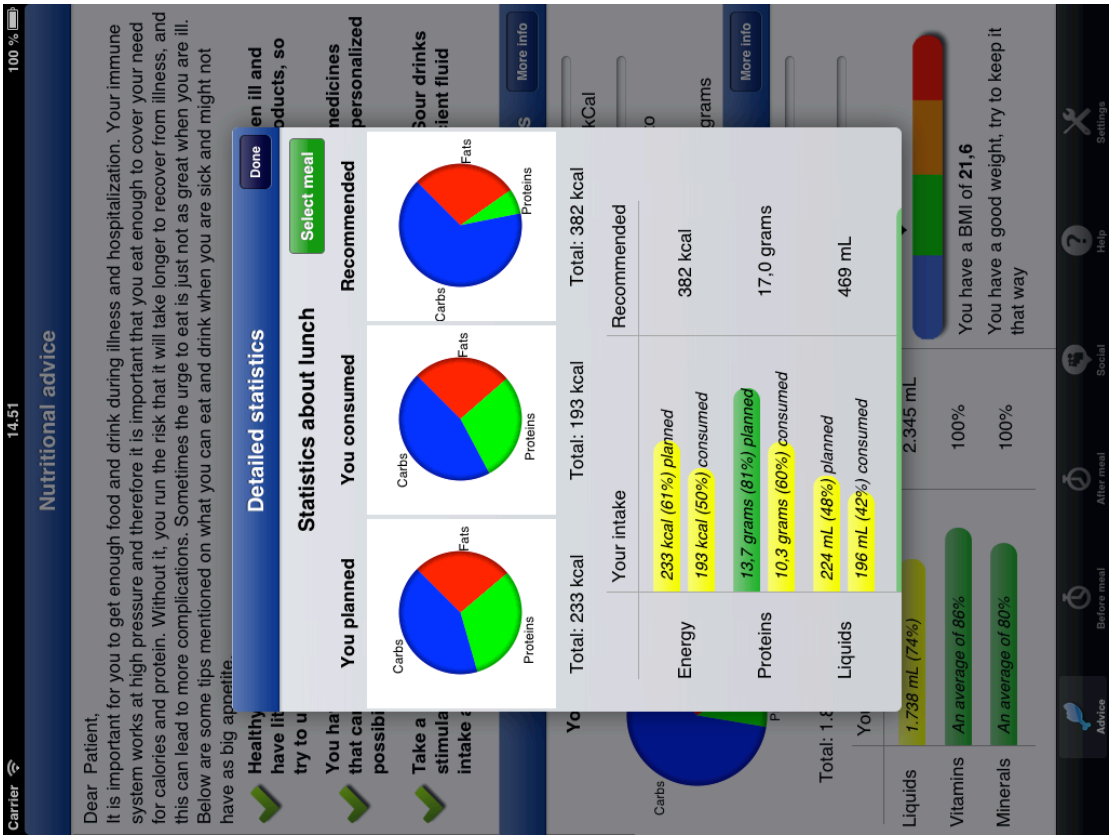

Figure 6.5: Detailed statistics in the advice screen

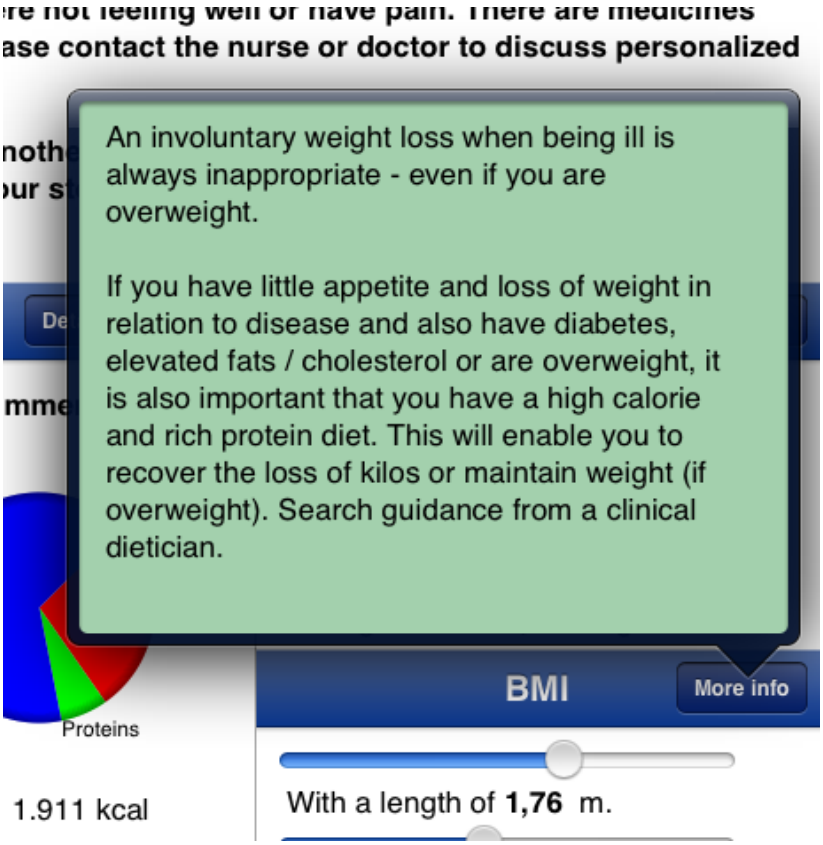

Figure 6.6: Additional information about BMI

The before and after meal screens are kept very much the same compared to the initial Photoshop designs. A difference is that the before meal screen doesn't display in the charts the intake of the entire day, only the intake for that specific meal (see figure 6.7). This is done to prevent the charts from getting too cluttered. The after meal screen (figure 6.8) is mostly the same as the before meal screen, but doesn't show the charts and has an option to make a picture. The questionnaire in the after meal screen doesn't display advice anymore since that is now in the advice screen. Due to the more options in the questionnaire (figure 6.9), the general satisfaction and remarks have been moved to a second page (figure 6.10). After completing the questionnaire the user goes automatically to the advice screen.

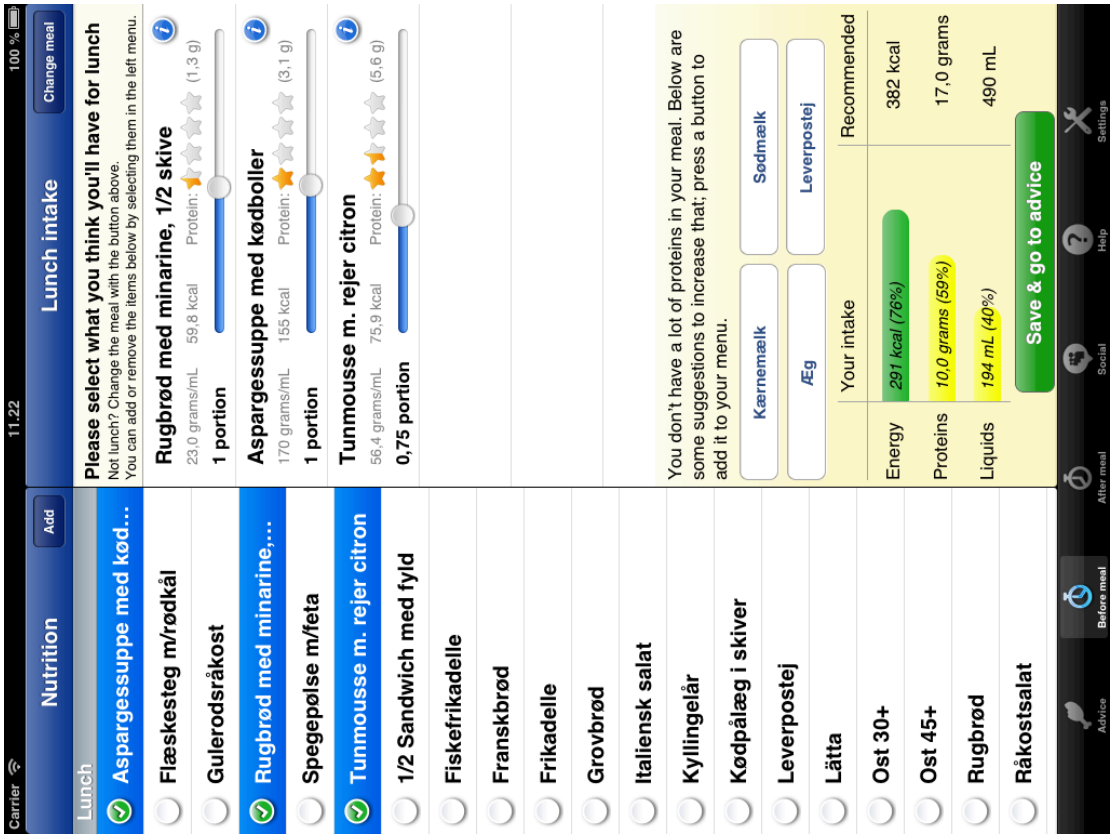

Figure 6.7: Before meal screen

Figure 6.8: After meal screen (in Danish)

Figure 6.9: Nutritional questions page 1

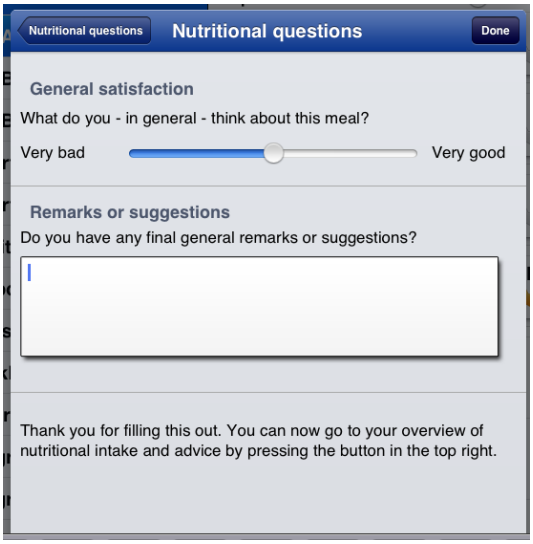

Figure 6.10: Nutritional questions page 2

The social screens and help screen have been made exactly the same as the initial designs (see figure 5.7, figure 5.8 and figure 5.9 for the designs). The settings screen (figure 6.11) has been changed in such a way that it wasn't necessary anymore to switch to different pages when changing a setting; all user settings are done on one page which makes it easier to understand for the user.

The application is completely bilingual in English and in Danish, as can be seen for example in figure 6.8. Lastly, there is a demonstration mode, which explains the functionality with screenshots and an overlapping textbox (see figure 6.12).

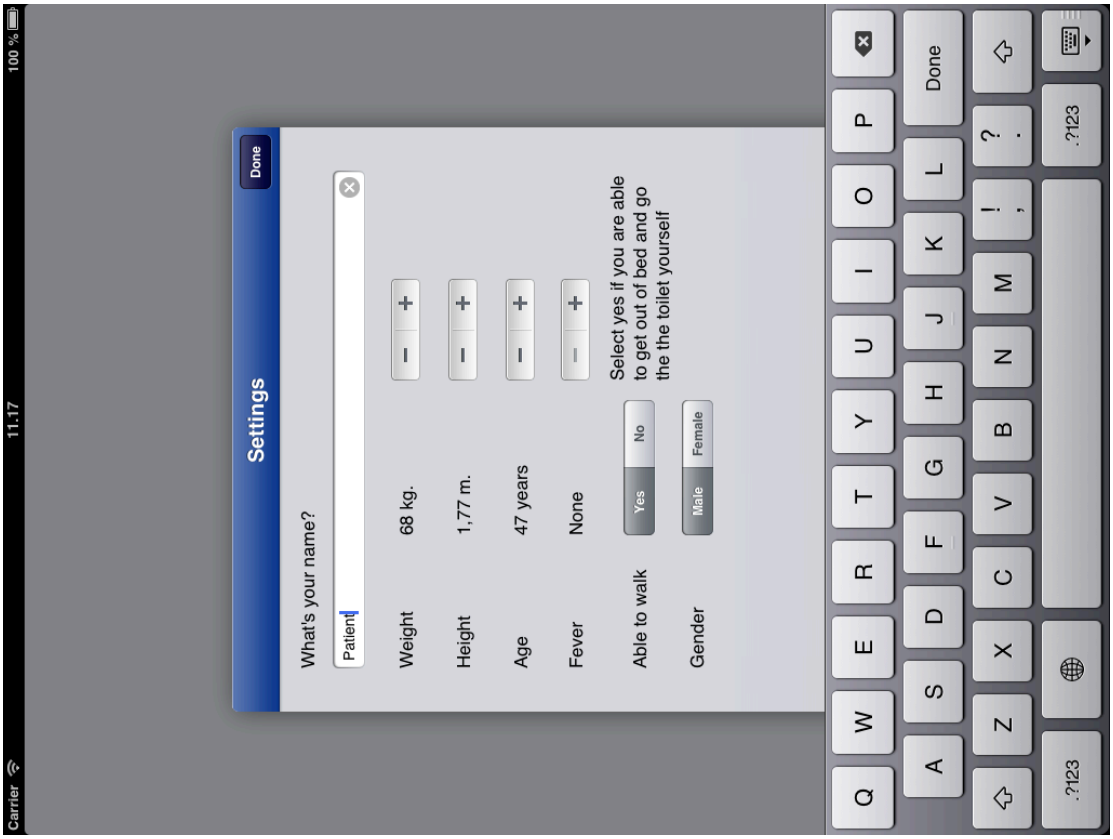

Figure 6.11: Settings screen

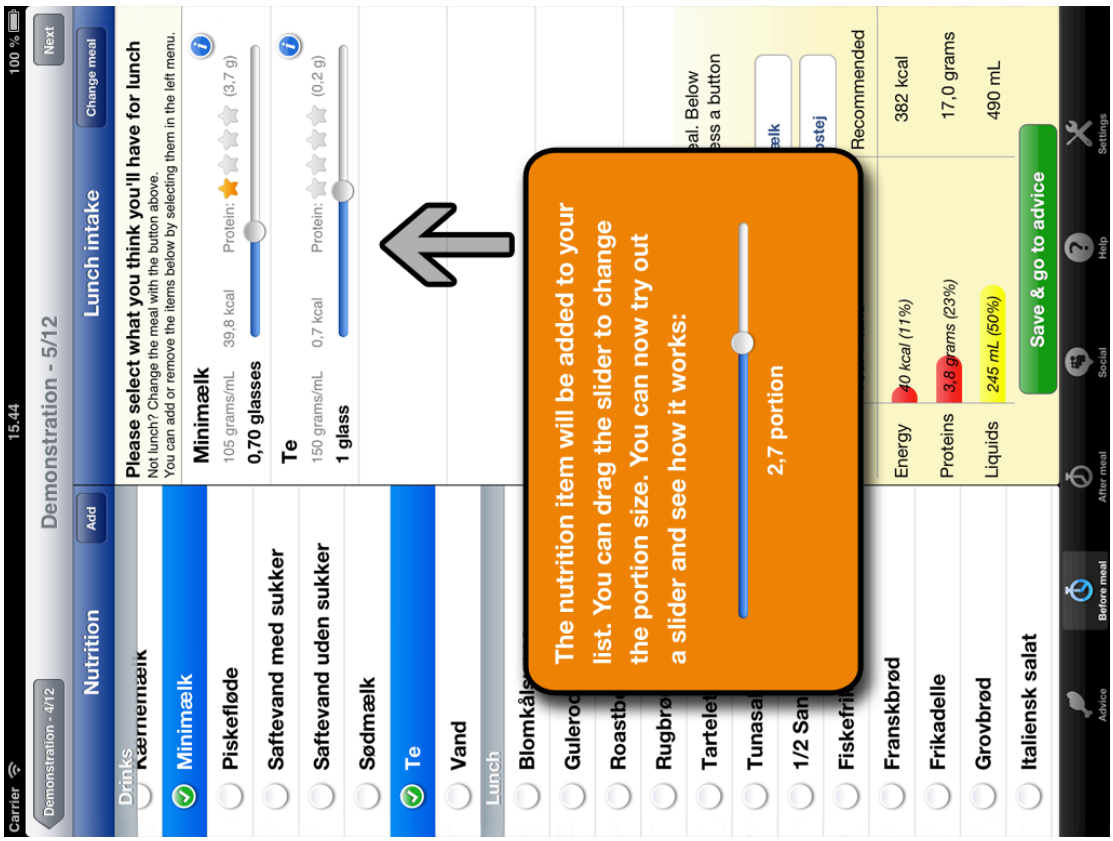

Figure 6.12: Demonstration mode explaining the before meal screen

6.9 Comparing final application to requirements

Chapter 4 listed the functionality the application should support. This section compares the requirements with the final application's functionality and is therefore an evaluation of the initial described functionality. This validation is part of the software life cycle and can help identify problems in the system, which can then be resolved in future iterations (Dix, Finlay, Abowd, & Beale, 2004). The requirements in chapter 4 are split up in a non-functional and functional part, as is done here.

6.9.1 Non-functional requirements

Performance: overall the system responds within a normal speed. There is a small delay when selecting a nutrition option from the list in the before or after meal screen. However, this delay is almost unnoticeable and has been concealed by a short transition when selecting a nutrition option.

Reliability: all data is stored in a database. A save operation is called every time the user changes the page or the tablet goes in standby.

Safety features: all data transferred over the Internet goes through a secure HTTPS connection. Files being sent are saved on an external server, with that specific folder being password protected.

Usability: because of the age group, it is tried to make the application as intuitive as possible. Due to the many screens and functionality, the application can be confusing for new users. The demonstration mode with screenshots helps to improve that. Interface elements (buttons, texts, etc.) have not been made too

small in order for users of higher age also to be able to interact with it comfortably.

Supportability: the system support both the English and Danish language fully. Switching between that however is unfortunately not possible in the application. This is because iOS language settings are done globally for the entire iPad in the main settings application. Circumventing this and make the switching possible in the application would have resulted in not being able to use many standard and good localization functionalities of iOS.

6.9.2 Functional requirements

There are in total 38 requirements formulated. However, as the application was developed, new knowledge and ideas arose. This is consistent with the software cycle described by Dix, Finlay, Abowd, & Beale (2004). It does mean that some requirements haven't been met, although that is not immediately considered as a failure. A list with whether requirements have been implemented can be found in table 6.1.

Most important non-implemented functionality is the changing of language and preferences & allergies. As can be read in the previous section 6.9.1, changing of the language can be done in the general iPad settings instead of in the application. Using the preferences and allergies of the user for the patient profile and advice was problematic since it would make the advice far more complicated. After discussing this with nutritional employees from the hospital, it was decided not to implement preferences and allergies because in reality it is rare and also for dietitians very difficult to handle.

Because of the researcher not mastering the Danish language, some functionality was not (fully) implemented. Mentioning positive feedback, increasing pleasure and hope and other motivational messages are not entirely in the application. Writing Danish texts for this proved to be too difficult. The persuasion theories of stages of change and eight step design process have not been incorporated as much as initially intended. Sections 9.2 and 9.3 discuss this in more detail.

Table 6.1: Realization of functional requirements

Require-ment	Imple-mented	Remarks
		Administrative settings screen
1	Yes	Administrative settings screen is in the settings screen.
2	Yes	Administrative settings screen is accessible via certain swipe movements.
3	Partially	Changing and creating a patient profile as well as sending the data to an external server is possible. Changing the language is not; this has to be done outside the application in the general iPad's settings.
		Patient profile
4	Yes	Multiple profiles is possible.

5.	Yes	The latest profile is automatically selected.
6.	Yes	The profile of a patient doesn't contain preferences and allergies, but it is possible to save the name and nutritional records. Furthermore it contains weight, height, age, fever, whether the patient is bedridden, gender and usage (log) information.
		Demonstrating the application
7	Yes	A demonstration mode is available.
8	Yes	Demonstration mode is consistent.
9	Yes	Demonstration mode is available in the help screen and can be started any time.
10	Yes	A disclaimer is part of the demonstration in the last screen of it.
		Before meal menu options
11	Yes	15 minutes before the meal an alert is given to open the before meal screen.
12	Yes	Menu options are available in the before meal screen.
13	Yes	Advices are given in the advice screen.
		After meal nutritional measurement
14	Yes	30 minutes after the meal an alert is given to open the after meal screen.
15	Yes	Menu options are available in the after meal screen.
16	Yes	The user can select the amount consumed.
17	Yes	A questionnaire can be filled in after inputting the consumed nutrition.
		Nutritional advice
18	Yes	There is an advice screen.
19	Partially	A distinction is made for all the meals instead of morning, afternoon and evening. This seemed to be more consistent with the before and after meal screens.
20	Partially	Most indicators in the requirements for nutritional advice are used by the system, except for the preferences and allergies. Also, indicators for insufficient fluidal intake aren't mentioned since dietitians in the hospital indicated that these aren't so accurate.
		Persuasion theories elements
21	Yes	The name of the patient is used in the text of the advice.
22	Yes	In the advice screen the loss of weight can be calculated for

		a certain period.
23	No	Mentioning positive feedback is not implemented.
24	Yes	There is a social screen.
25	No	There is no option to post to Facebook or Twitter since the iPad doesn't have access to the Internet.
26	Partially	Advices were created with help from dietitians from the Aalborg hospital. However, placing links to external websites would be confusing; since there is no Internet connectivity opening it wouldn't work.
27	Yes	Logos of Aalborg University, University of Twente and Aalborg Sygehus are shown in the demonstration mode.
28	Partially	Social acceptance is implemented in the social screen. Increasing pleasure and hope is not really incorporated in the design.
29	No	Notifications don't have a motivational message. This is because every time the same motivational message is annoying and diversifying it requires many different texts. All these texts should be translated to Danish in a way that it's still motivating, which proved very hard to do.
30	No	Stages of change are not taken into account for the advice. See section 9.2 for more details about this.
31	Yes	Big compliments and rewards are not in the application.
32	Yes	Eating or trying something new is implemented in the list of nutritional options and textual advice. Decreasing the attractiveness of not eating enough is done in the weight loss section in the advice screen by showing the consequences. The importance of good nutritional intake is explained textually in the advice screen.
33	Yes	Two-sided messages exist in the advice screen and especially behind the more information buttons of weight loss and BMI.
34	Yes	It is not mentioned that persuasion is the goal.
35	Yes	The nutritional options list has an "add" button for new nutrition items.
36	Partially	The eight step design process has been considered during development, but couldn't fully be used. See section 9.3 for more details about this.
37	Yes	There is no need for nurses to assist.
38	Partially	No other sounds than the notifications are implemented. However, standard iOS sounds for scrolling a list, closing the iPad or typing on a keyboard couldn't be disabled.

7 Testing plan

This chapter will discuss how the testing of the application in the hospital will be done. Some background information and working procedures about the hospital where the testing will occur are clarified in section 7.1. Section 7.2 will continue with the discussion of how nutritional intake will be measured, which will later be compared to the ideal nutritional intake mentioned in section 7.3. The target group of the research is defined in 7.4. The testing methodology in combination with the reasoning behind it why the experiment is set up this way is discussed in section 7.5. Section 7.6 will explain the final part of the experiment, the debriefing of users with a questionnaire. Closing section 7.7 will go through the procedure chronologically, to clarify and summarize the entire testing procedure for one patient.

7.1 Domain analysis

Before discussing the testing methodology of the application, it would be useful to know the environment where the application is used. This information is gathered by interviews and visits to the Aalborg hospital. The main kitchen is the starting point of the food and drinks. Here, the breakfast, lunch and dinner are prepared. Besides the three main meals, there are also three in between meals: after breakfast/before lunch, after lunch/before dinner and after dinner. For every main and in between meal about 800 portions are prepared. On average, more lunch than breakfast is prepared, to provide food for ambulant patients (that aren't staying for an entire day) as well. For 10 to 30 patients a special meal is prepared, e.g. for gluten intolerance, non-pork, vegetarian or allergies. There are about 35 wards; half of them have an own kitchen where they finalize the preparing of the main meals. The other wards receive the finished food and only have to serve it.

The wards with their own (satellite) kitchen receive once a day a food cart with semi-finished products or ingredients for all main meals and in between meals. Bread, salad and vegetables have to be cut in the ward kitchen, but food as for example soup, lasagne or meatloaf only have to be warmed up (preparations are done in the main kitchen). Plates and cutlery is in the kitchen from the ward and dishes are done at the ward as well.

The wards without a kitchen receive three times a day for every main meal a food cart. The cart includes plates, cutlery, food and in between meals. This is returned afterwards to the main kitchen and dishes are done in the main kitchen. Food carts in the kitchen ready to go to wards and an open food cart are displayed in figure 7.1 and figure 7.2, respectively.

Figure 7.1: Food carts in the kitchen

Figure 7.2: Food card on the ward

One of the nurses or service staff, depending on department priorities, serves the meal from the carts at one central point on the ward. Patients that can walk will come to the cart; for patients that cannot nurses will pick up the food/drinks and bring it to the patient. For breakfast the patient can choose from a standard assortment of food and drinks. Lunch and dinner are changed every day, in a menu cycle of 21 days; there is also a summer and winter cycle to include seasonal foods in the menu. Lunch consists of soup, salad, bread and some meat. For dinner there are two options, but some wards decide to choose always one of the options to decrease food wastage of the least-chosen food.

Patients cannot decide in advance what they would like to have, but at the cart it is possible to request more or less of something. One of the nurses or service staff at every ward orders the number of portions two days ahead. If there are unexpectedly more patients in the ward than at the time of order, the nurse calls the kitchen and requests more ingredients or portions. Although a portion should be for one patient, they know that patients aren't big eaters, so they order fewer portions than there are patients. Leftovers of cold meals are kept in the refrigerator for if patients would like to eat more at in between meals or when a patient has missed a meal because of e.g. surgery. Moreover a freezer assortment of small meals is kept in all departments for nurses to prepare.

Because patients don't get the same portion size (on request it can be more or less of some ingredient), it is hard to use the choice of menu for exact calculations of nutrition intake. Figure 7.3 shows an example of a lunch plate for a patient. It can be seen that there are nine different ingredients, all with their different calories and protein values. Choosing fewer carrots and more shrimps changes the nutritional intake values slightly.

The hospital therefore uses average nutritional values to measure intake. The paper forms that are used for intake registration of patients have the option for e.g. lunch small, medium or large. The energy and protein values of a small lunch are taken from measurements of the 42 possible lunches (3-weeks cycle with summer and winter season). It is assumed that variances in portion size and differences in chosen ingredients don't have that much effect on energy and protein levels. It would also be too much work to weigh and register everything the patient consumes.

Figure 7.3: Example of lunch meal in the hospital

7.2 Measuring nutritional intake

A common way of measuring the nutrition intake of patients is keeping records of every meal the patient has consumed. This dietary diary is often administered in the hospital by the nurses. A study that compared the dietary records with the actual energy expenditure concluded that dietary records are "a valid instrument for assessing food and water intake". A 7-day period was recommended for measurements. The actual energy expenditure was measured using the Double Labelled Water method where non-radioactive isotopes are put in water and the elimination (absorption) rate in the body is measured over time (Persson, Elmståhl, & Westerterp, 2000). For this research the Double Labelled Water method isn't possible because this requires laboratory testing for which funding would be necessary.

For the same reason as the Double Labelled Water method, the weighing of incoming and outgoing food isn't possible either because it would require too much time from the nurses and isn't possible for only one researcher. Instead a form is used where the patient has to fill in nutritional intake himself. This form is created and currently in use by the nutritional department from the hospital. For all meals there are options for kinds of meals (e.g. soup, bread, yoghurt) but not going into the details of ingredients (e.g. tomatoes, kind of marmalade, kind of meat). The standard amounts are showed (e.g. 100mL, 1 piece) and entering the number or percentage of how much is eaten makes it possible to calculate the energy (kcal) and proteins (grams). Energy and protein levels for general food options (e.g. lunch in general) are calculated by looking at the 42 possible lunch options in the hospital and calculating the average from that for a standard portion size.

Important for dietary diaries reporting is that it should be done as soon as possible after the nutritional intake. “The longer the delay in recording dietary intake, the greater is the risk of recall bias”. Recordings long after the facts, called back-fill, should be prevented (Burke, et al., 2005).

When considering recording nutritional intake with a tablet application, some lessons learned from other research can be valuable. When the target group has low literacy, it is important to keep this in mind and do as much as possible from the interface in a graphical way (Welch, et al., 2010). Another improvement point mentioned in the development of a self-monitoring dietary application was that an alarm could increase the compliance rate of filling in the nutritional intake. The registration of the nutrition was done very quickly, on average in 30 seconds, but users tended to forget it (Welch, Dowell, & Johnson, 2007). Interestingly, the terminology of a nutritional registration application can also make a difference. When changing the name from PDA or digital computer to simply “tool”, the acceptance and adoption increased (Connely, Faber, Rogers, Siek, & Toscos, 2006).

The kitchen knows exactly for all dishes on the menu (and even for all ingredients) the nutritional values (amount of calories, protein, fat, carbohydrates and fibre) of a portion. This is necessary to provide a balanced menu for hospital patients, which is obligated by Danish regulations. These numbers are used for the application to measure the nutritional intake, as explained in section 6.1.

However, as been mentioned in the previous section, food that is served on the ward is not completely the same amount as a portion. The nurse often orders fewer portions than there are patients and the patient can decide to take less food than the suggested portion. Therefore, during the user study the paper forms from the hospital are used for measuring nutritional intake. Although they measure intake on a more general level (e.g. medium dinner instead of the specific ingredients), these paper forms are based on averages, are currently in use in the hospital and are apparently reliable enough for medical purposes. Using the paper forms from the hospital also has the advantage that nurses can help the patient with filling in and earlier measurements in the patient’s file can be used.

7.3 Ideal nutritional intake

There are various methods to calculate the ideal nutritional intake for people. Most accurate is indirect calorimetry, which measures temperature changes (called thermogenesis), consumption of oxygen or production of carbon dioxide because of metabolism. This makes it possible to measure the basal metabolic rate (BMR), which is the amount of energy expended in a resting (but awake) state (Powell, Paluch, & Blair, 2011). 60% to 75% of the total energy expenditure (TEE) is from the basal metabolic rate of maintaining major body functions and another 10% for the digestion of food (Poehlman, 1989). The third aspect of TEE is the physical activity-induced energy expenditure (PAEE), which accounts for 15-30% of the TEE, but is the most variable component of TEE (Choquette, Chuin, Lalancette, Brochu, & Dionne, 2009). Other factors of TEE, but less common on average people, are growth (35% of TEE in first three months after

birth, 5% at 12 months, 3% at age 2 and negligible in late teen years), pregnancy and lactation (Food and Agriculture Organization of the United Nations, 2004).

The basal metabolic rate is influenced by "factors as age, sex, body size and composition, body temperature, thermogenic hormones, and prior exercise". It provides energy for all the organs of the body in rest (Poehlman, 1989). The basal metabolic rate can be estimated using a formula, which was developed in 1919 by J. Arthur Harris and Francis G. Benedict and is therefore called the Harris-Benedict equation. Using an indirect calorimeter the basal metabolic rate (BMR, in kilocalories per 24 hours) was measured, which led to the equation:
*BMR men (kcal / day): 66,4730 + 13,7516 * weight + 5,0033 * height – 6,7550 * age*
*BMR women (kcal/day): 655,0955 + 9,5634 * weight + 1,8496 * height – 4,6756 * age*

Weight is in kilograms, height is in centimetres and age in years. To calculate the recommended daily calorie intake, the BMR is multiplied with a variable value for no exercise (1,2) to very heavy exercise (1,9). Some new studies have compared the Harris-Benedict formula with measured metabolic rate, and often found a 5% difference (Frankenfield, Muth, & Rowe, 1998). However, a study applying Harris-Benedict equation to malnourished patients "seriously question[ed] the reliability of the Harris Benedict equations in malnourished patients". The Harris-Benedict equation used a normal and healthy population to derive the formula, but hospital patients especially with undernourishment apparently fall outside the scope of the formula (Moza & Shizgal, 1984).

In this research recommendations from the Danish government for hospital food will be used, since the hospital where the experiment will take place uses these guidelines of Ministeriet for Fødevarer, Landbrug og Fiskeri (2009). The calculations for the ideal energy and protein intake are similar to those of the Harris-Benedict equation, but instead of applying a linear formula, different categories have been used (weight, patients mostly laying in bed or being able to walk, fever, whether patient needs to increase weight). Advised energy and protein intake for 24 hours is showed in table 7.1. Energy values are in kilo joules (kJ); 1 kcal is about 4,18 kJ. When the patient has a fever the amounts need to be multiplied with a certain factor; for 38˚ this is 1,2, for 39˚ this is 1,3 and for 40˚ this is a factor of 1,4. When the BMI is higher than 30, there is a completely other calculation for energy and protein needs. For patients laying in bed the energy is weight * 85kJ and for protein weight * 0,9 grams; for patients being able to walk the energy is weight * 100kJ and for proteins weight * 1,1 grams.

Table 7.1: Energy needs in kJ and the protein needs (between parentheses) in grams for hospitalized patients, per 24 hours. Source: Ministeriet for Fødevarer, Landbrug og Fiskeri (2009).

<table>
<tr><th></th><th colspan="2">Keep weight</th><th colspan="2">Increase weight</th></tr>
<tr><th>Weight</th><th>Laying in bed</th><th>Walking</th><th>Laying in bed</th><th>Walking</th></tr>
<tr><td>90kg</td><td rowspan="2">9 000
(95)</td><td rowspan="2">10 000
(105)</td><td rowspan="2">11 000
(115)</td><td rowspan="3">13 000
(135)</td></tr>
<tr><td>85kg</td></tr>
<tr><td>80kg</td><td rowspan="2">8 000
(85)</td><td rowspan="2">9 000
(95)</td><td rowspan="2">10 000
(105)</td></tr>
<tr><td>75kg</td><td rowspan="2">11 000
(115)</td></tr>
<tr><td>70kg</td><td rowspan="3">7 000
(75)</td><td rowspan="3">8 000
(85)</td><td rowspan="2">9 000
(95)</td></tr>
<tr><td>65kg</td><td rowspan="2">10 000
(105)</td></tr>
<tr><td>60kg</td><td rowspan="3">8 000
(85)</td></tr>
<tr><td>55kg</td><td rowspan="3">6 000
(65)</td><td rowspan="2">7 000
(75)</td><td rowspan="2">9 000
(95)</td></tr>
<tr><td>50kg</td></tr>
<tr><td>45kg</td><td rowspan="2">6 000
(65)</td><td rowspan="2">7 000
(75)</td><td rowspan="2">8 000
(85)</td></tr>
<tr><td>40kg</td><td>5 000 (55)</td></tr>
</table>

Interesting to know is that 1kg weight loss corresponds to 20 megajoules (MJ). When the patient is daily eating 2MJ too little, for a week that will sum up to a loss of 0,7kg. But for 1kg gaining weight, you need 30MJ. Recovery to the original healthy weight is therefore difficult (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2009).

In the Aalborg hospital, the dietitians' goal is to keep the weight of the patient constant. It is not considered realistic to increase the weight of patients to a level of a normal healthy person. After the patient is discharged from the hospital, he or she will probably gain weight again. The two most right columns of table 7.1 are therefore generally not used in the Aalborg hospital. For patients with obesity it is not the intention to let them loose weight, as the muscle strength is the first that is lost, and the immune system will be weakened, which will not help with recovery.

The Danish government has also set up recommendations for the consistency of hospital food. The energy division for hospital food is on average 18% protein, 40% fat and 42% carbohydrates for patients at nutritional risk. Compared to normal food that has 15% protein, 30% fat and 55% carbohydrates, the hospital food for patients at nutritional risk has more fat and proteins. The advised division of energy throughout the day for hospital food is as follows: 20-25% in the morning, 20-25% in the afternoon, 25-30% in the evening and 15-30% as in between snacks. Patients with a small appetite eat less in the morning, afternoon and evening, but should have higher energy intake from in between snacks (30-50%) (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2009). However, increasing the number of in between snacks does not necessarily result in higher

energy and protein intake (Holst, Mortensen, Jacobsen, & Rasmussen, 2010). Dietitians at the Aalborg hospital advise patients at nutritional risk to take a daily vitamin and mineral tablet, because patients are advised to consume higher levels of protein and fat, there is less room in the menu left for fruits and vegetables.

Besides food intake, drinking enough fluids is also important. A person with not much physical activity needs around 2500mL a day. 300mL is obtained from metabolic reactions, 1000mL from food and 1200mL has to be from beverages. But illness can increase the needs enormously. Fever can cause the patient to transpire more, which increases the needs by 20%. Patients with burn wounds can lose 4-8 litres a day, diabetes mellitus and especially diabetes insipidus patients may need an additional 10 litres, and diarrhoea, vomiting and internal infections can require 5-10 litres a day (Ministeriet for Fødevarer, Landbrug og Fiskeri, 2009). The amount of liquid intake can vary for certain kinds of patients and is therefore more difficult to determine than for food. In Aalborg hospital different criteria (or a combination of it) is used: 35mL per kilogram bodyweight (40mL for patients with fever), the colour of the urine (dark urine is a sign of dehydration), recommendations for patients with certain diseases (e.g. kidney patients in dialysis) or electrolyte concentrations in blood samples.

7.4 Target group

The main target group for the experiment will be patients in the hospital. But certain patient groups cannot participate in the experiment because of various reasons. The exclusion criteria for the participants in the experiment are:

- Patients younger than 18 years old. Parental consent would be needed and the ideal nutritional intake is different for children who are still growing.
- Patients staying shorter than 48 hours. The experiment time is 48 hours, as will be explained in section 7.5.
- Patients receiving tube or parenteral feeding. These patients are often eating nothing or hardly anything and trying to increase the nutritional intake would be extremely difficult. For these kinds of patients, the reason for not eating is not a motivational element that can be improved by persuasion, but has more to do with illness and impossibility to eat by themselves.
- Patients visually impaired. For them, it would be impossible to control the tablet application.
- Patients not allowed to eat during the experiment because of e.g. surgery or medical treatment.
- Patients that are pregnant or gave birth. The ideal nutritional intake for this group of patients is different.
- Patients unable to communicate coherently, e.g. dementia, severely mentally and physically impaired.
- Patients that are terminally ill. Persuasion on these patients will probably have less or no effect, since the motivation to do anything will possibly be completely different than for other patient groups.
- Patients hospitalized with the main reason of undernourishment, e.g. anorexia or bulimia nervosa. Although these patients will probably

receive artificial tube or parenteral feeding, the nutritional intake is not increased by motivation but more likely by psychotherapy.
- Patients being moved to another ward or room during the experiment. Changes in the environment can change the appetite.
- Patients receiving an alternative menu because of preferences or religious reasons (e.g. vegetarian) or have dietary constraints, e.g. for allergies, lactose or gluten intolerances. Incorporating these special meals into the application takes a lot of time, while only 10 to 30 patients in the hospital make use of this.
- Patients not providing written consent to the experiment.

7.5 Testing methodology

Broadly speaking, the goal of this research project is to see if a tablet application can have influence on the nutritional intake of patients. Using persuasion techniques discussed in chapter 3 is a means to do that, but measuring persuasion by itself isn't possible and therefore the results of it (nutritional intake) are taken into account. The methods to measure the nutritional intake have been discussed in section 7.2, and the targeted nutritional intake is described in section 7.3. In short, an attempt will be made to bring the measurements of current nutritional intake closer to the value of targeted nutritional intake.

Ideally a perfect testing methodology excluding and including multiple variables would be preferred, but in reality there are limited resources. There is only one iPad available and the testing should be done within one month. Because individual patients can have a preference for breakfast or dinner, the measurement should be at least 24 hours or multiples of 24 hours. But with a 24 hour testing duration and a month time, a theoretical maximum of 31 patients can test the application, which makes it unlikely that significant change can be proved. Nevertheless, a small improvement (although not significant) would also be good and qualitative information (see next section, 7.6) can also be useful.

The most important factor to measure in the experiment is nutritional intake, thus being the dependent variable. The independent variable is the usage of the application. Introducing more independent variables (e.g. applying different persuasion techniques or different designs of the application) would be useful information, but a factorial design of the experiment would require more testing participants (for an between-group design) or make it even harder to have results with significance (Lazar, Feng, & Hochheiser, 2010).

As for the choice between-group and within-group design: between-group (where the tablet-patients would be other patients than the non-tablet-patients) has the advantage of preventing learning effects, but the comparing of results between groups is practically impossible. Patient in both groups would need to have the same characteristics in e.g. age, sex, BMI, health problems and nutritional status to be able to compare the results. Because of high variances between results of patients, having significant results would be difficult without a very large sample size. Within-group makes it possible to test the nutritional intake from an individual patient in status quo to the results of the nutritional intake with the tablet. To isolate learning effects, for (a randomized) half of the

experiments the status quo is first followed by the tablet intervention, and for the other half of the experiments the tablet intervention is first followed by a non-tablet measurement (Lazar, Feng, & Hochheiser, 2010). This randomization helps also factoring out possible increases of the patient's appetite in time due to health improvements. In other words: because on day 2 the patient could have more appetite (compared to day 1) because he/she recovered a bit, but the tablet application is used for half of the patients on day 1 (and the other half on day 2); nutritional intake results with the tablet are therefore averaged out between day 1 and day 2.

The hypothesis of the experiment is:
Patients who use the tablet application have nutritional intake that is closer to the ideal nutritional intake than patients who do not use the tablet application.

This leads to the following null hypothesis and alternative hypothesis:
H0: *There is no difference in the nutritional intake compared to the ideal nutritional intake when using the tablet application.*
H1: *There is improvement in nutritional intake compared to the ideal nutritional intake when using the tablet application.*

It can be argued that usage of the application by itself can already have a positive effect on the nutritional intake of the patient. The persuasive elements may have not completely caused it. Behaviour can be changed just because the experiment results in attention for the testing subject; this is often called the "Hawthorne effect" to the study that showed that making it darker as well as lighter in a factory increased workers productivity (Levitt & List, 2009). Although the application usage being the only independent variable (and not the persuasion elements) isn't ideal for an experiment, the lack of more resources makes it impossible to have two groups both using tablets and register nutritional intake with it, but only half of the patients using the persuasive functionality. This would test only the persuasive results, but requires twice the amount of tablets or halves the sample size. It is therefore decided that the hypothesis and experiment is about the tablet application usage in general instead of persuasion elements in particular.

This experiment will also not take long-term effects into account. Nutritional intake is measured for 48 hours, but it can happen that by using the application the patient gets a better understanding about nutrition and is more motivated to improve nutritional intake. Hospital patients are however difficult testing subjects, in fact medical studies in general are well known for their complexity since there are many variables involved which are difficult to control. The hospital patient can in the long term have improved nutritional intake because of the application, but it can also be caused by e.g. recovery, advices from nurses, different menus, mentally feeling better, less pain, etc. It is impossible with the available resources for this study to control these external variables and examine the long-term effects.

It is important to prevent systematic errors in the results, also called bias. According to Lazar, Feng, & Hochheiser (2010), there are five major sources of systematic error. Each will be discussed along with ways how this is handled in the research.

- **Measurement instruments**: the measurement of the nutritional intake will be done on paper. This paper form is currently in use by the hospital to measure the intake of patients, and can therefore be considered reliable. The application will also measure the nutritional intake, but since that measuring method is different, the results of the paper form are not completely comparable to the data of the application. Patients are asked for every main meal and in-between meal to register what they've eaten/drunk. Because this is filled in so frequently, the chance of forgetting something becomes smaller. After every day the list with nutritional intake will also be checked by the researcher for possible mistakes or omissions.
- **Experimental procedures**: a particular aspect to pay attention to with hospital patients is that the application should not create fatigue. Long and uninteresting tasks could lead to underperformance. Another important aspect is a standardized procedure for giving instructions. Differences in wording in the procedure can cause different results (Wallace, Anderson, & Shneiderman, 1987). A written document prior to the experiment explaining the experiment will be given to the patient, and additional explanation about the application will be given in the application itself.
- **Participants**: the target group for hospital patients have been described in section 7.4. It is expected that the hospital where the experiment is held will be representative for a hospital environment (at least for Western society standards) and including other hospitals brings no added value.
- **Experimenter behaviour**: intentional or unintentional, a researcher can influence the user by making positive or negative remarks or insinuate something. Lazar, Feng, & Hochheiser (2010) recommend the experimenter to be neutral, calm, patient, arrive in time for the experiment, have preferably two experimenters and have standardized procedures. Standardized instructions will be used (as mentioned at the bullet "experimental procedures") and the experimenter will try to be as neutral as possible. But most importantly, the experimenter will not be present when the patient is using the application during the day.
- **Environmental factors**: a division can be made between physical environmental factors and social environmental factors. Physical environmental factors are e.g. noise, temperature, lightning, vibration and humidity. Social environmental factors can be the number of people in an environment and the relationship between them and the participant (Lazar, Feng, & Hochheiser, 2010). Both physical and social environment cannot be influenced for the experiment as testing needs to be done at the patient's bedside. However, when comparing both situations (patients with and without using the tablet application) patients remain in the same environment.

7.6 Debriefing

After the experiment has been completed, the patient will be asked a few questions. The questionnaire and its procedure are very similar to that of the usability testing (see section 5.3). A short interview is done after (and not

before) the questionnaire to prevent biased responses (Brooke, 1996). This interview is not structured and the patient is asked about possible problems, his experiences, interesting or unusual input into the program and any other remarks the patient may have. A large part of the questionnaire is based on the Standardized Computer System Usability Questionnaire at IBM (Lewis, 1995) with five-point scale answers. Questions regarding productivity, efficiency and effectiveness have not been used because that's not the goal of the application and results of answers would not be useful. Compared to the questionnaire of the usability testing, two questions about error messages and help information have been added, while two questions about the simplicity have been removed to make the questionnaire shorter and because they overlapped with other questions.

Besides the questions about the usability aspects of the application, it is also important to know what the impact of the application is on the user. The goal is to improve nutritional intake, and although this can (partly) be measured by itself, it is also important to know the effect of the application on people. Ten questions have therefore been included in the questionnaire about the experiences with the application regarding nutrition in general and the user's nutritional intake.

As with the usability questionnaire, the five-point scale questions have some space for remarks. Besides the closed questions, there are also open-ended questions about positive and negative aspects, the separate screens in general and closing remarks. This helps to retrieve some qualitative data besides the quantitative, which can be important since the expected number of user tests is not high. The entire questionnaire (in Danish) can be found in appendix A.7; the translation of it can be found in appendix A.8.

After finishing the questionnaire the user receives a debriefing form, which can be found in appendix A.6. The debriefing is based on the template of the Psychology Department of Harvard University (2012). It describes the goal, set-up and hypothesis of the study and lists contact information. The half of the participants that started with the iPad application and still have to do a second day of paper-based nutritional monitoring receive the debriefing form the day after. This is done to prevent them changing the nutritional intake on the second measuring day. Instead of the debriefing the participant is asked if he/she has any questions and was explained that a second day of measuring nutritional intake was necessary for verification. After the second day of paper-based monitoring the participant receives the debriefing as well.

7.7 Summary of procedure

For clarification, this section explains the testing procedure chronologically for one patient. First a ward is contacted whether there are patients available for the user study and fit in the target group (see section 7.4). If so, the patient is contacted and asked to cooperate in the experiment.

If the patient is willing to participate, he or she receives a consent form. This form is based on the template of the Psychology Department of Harvard University (2012) and provides some background information about the experiment. This is another – more extended and detailed – consent form than

used for the usability testing (see section 5.3 and appendix A.1) because this experiment demands more from the users and targets a more vulnerable user group. However, Aalborg hospital has also its own consent form from the ethical committee, which is therefore mainly used. The more extended consent form with background information is therefore used as additional information about the study and given as such to patients. The consent form of Aalborg hospital is in Danish, the additional information is in English. Patients not able to read English receive a spoken explanation of the study. The consent form including its additional information can be found in appendix A.4.

It is decided whether the patient will use the iPad the first or the second day. Regardless, the patient should register the nutritional intake for 48 hours on the standard hospital paper forms. This makes it possible to see if there is an improvement of nutritional intake with the iPad instead of without it.

Before starting with testing, the iPad is made ready. The menu of the day (lunch and dinner) is put in, and name and other information of the patient is inserted. The user gets an explanation of the application, the demonstration included in the application is used for this, and can ask questions about it. During the 24 hour testing help can be requested for usage of the iPad application by calling a phone number.

After the 24 hours of using the application, the patient is asked to fill in a questionnaire and a small interview will be done to ask the patient for his experiences. If that was the second day of nutritional intake registration with paper the experiment is finished and the user receives a debriefing form. Otherwise the debriefing form will be given 24 hours later.

8 Results of user study

The testing plan explained in the previous chapter has been executed in Aalborg hospital, and results of this are explained in this chapter. The first section 8.1 will mention some of the general experiences with the user study. Section 8.2 continues with the results of the nutritional intake. The application itself also contains useful information, which is presented in section 8.3. After the user study the patient was asked to fill in a questionnaire and a small interview was held; results from this are mentioned in section 8.4. A complete discussion of all the results is done in section 8.5.

8.1 General experiences with user study

Over a period of a month, in total 11 patients were found and fully completed the user testing (one patient stopped during the experiment). In advance, the expectations of number of test users weren't very high because of the limited time and resources (only one iPad) available. Afterwards can be concluded that even less people than expected used the application because of various difficulties, which will be discussed in this section.

Finding patients was mainly done with the help of the head of clinical nutrition research and nurses from the hospital. Making contact with the nurses – especially the head of a ward since they were the ones making the decision about the participation of the ward with the study – took time and since they were always busy was sometimes difficult. A suitable patient was then looked for, the patient was asked and if the patient was willing to cooperate the experiment was started. Many also declined because of feeling too tired, not feeling well or simply didn't want to.

Four wards took part in the research. The first ward has mainly gastroenterology patients (problems with digestion) in which three patients participated. The second ward is more general with infectious deceases and had only one patient. The third focuses on lung patients and there were three patients here. The fourth ward also has many gastroenterology patients, but then from surgery and four patients were found there. The next section shows which patient came from which ward, since the numbering of wards is consistent. The diversity in wards has the advantage of a diverse demographic group, which is better compared to having only one ward.

After finding a patient the application and procedure had to be explained. Around half of the patients didn't speak English at all or well enough, but luckily often nurses helped out with translation and explanation. Receiving explanation from nurses instead of only a researcher probably also increased the willingness to use the application.

In general it took a lot of time per patient for one experiment. Making contact with a ward, finding a patient, explaining the application, putting lunch and dinner of the day from the MasterCater system in the application (see section 6.1, takes about an hour), debriefing, getting paper forms of the nutritional intake and calculating the nutritional values from this. During the testing period a second iPad became available, which made it possible to conduct the experiment with more users.

The paper forms used by the hospital to measure nutritional intake of patients, are in this research used to see whether there is an effect in nutritional intake when using the application. However, sometimes these paper forms tended to get lost on the wards, which can be seen in the results in the next section. In practice it was also not (always) possible to decide whether the iPad was used the first or second day, as described in the methodology. It takes time for nurses to register the intake, which is why existing nutritional data was used if it was available. In practice it also turned out that when using the iPad on the second day and only the paper registration on the first day, it happened that the patient went home the second day, not have been using the application. To have at least some results it was often decided to let the patient use the application as soon as he was found willing to. This led to less randomization in deciding which patients use the iPad on the first or the second day.

8.2 Results of nutritional intake

The complete methodology has been elaborated in section 7.5. It is a within-group experiment, with one independent variable (application usage), which has only two conditions (usage or non-usage). Therefore a paired-samples t test should be applied. Also, since the hypothesis is formulated as an improvement instead of change, it should be a one-tailed t test; in that case "a t value that is larger than 90% confidence interval suggests that the null hypothesis is false and that the difference between the two means is significant" (Lazar, Feng, & Hochheiser, 2010). The statistical program SPSS is used for this.

Table 8.1 lists the on paper recorded nutritional intake. For this the standard paper forms of Aalborg hospital were used. The table shows the nutritional intake of the patient on the day the iPad application was used, and another day the application wasn't used ("comparison day"). In the night the hospital staff processes the paper forms by calculating the energy, protein en sometimes liquids, states this numbers in the patient's file and then throwing away the original paper form. Quite often there was therefore only energy, protein and sometimes liquids information available in the patient's file, which is why only these dependent variables are used in the comparison. Comparison of whether all nutritional intake was inserted correctly in the application was for this reason also not possible, because often there was no paper form anymore to compare it with.

Table 8.1: Comparison of the on paper registered nutritional intake with and without the application

		Comparison day			iPad day			Delta		
Patient	CD	E	P	L	E	P	L	E	P	L
P2W1	–	–	–	–	1105	43	850	–	–	–
P3W1	-1	2280	58	–	3824	141	2100	+68%	+143%	–
P4W2	+1	2361	86	1800	1277	31	1600	-46%	-64%	-11%
P5W3	-5	1462	48	1800	***1447***	***43***	***1723***	-1%	-10%	-4%
P6W4	-2	2095	61	1775	1724	96	2225	-18%	+57%	+25%
P7W3	–	–	–	–	***1735***	***49***	***1699***	–	–	–
P8W1	+2	1956	69	1050	1300	43	–	-34%	-38%	–
P9W4	+1	3675	82	3000	1390	52	1775	-62%	-37%	-41%
P10W4	-1	2156	49	1885	575	16	–	-73%	-67%	–
P11W3	+1	1688	73	1800	1775	84	1350	+5%	+15%	-25%
P12W4	-1	1480	50	1450	***1872***	***95***	***2130***	+26%	+90%	+47%

E stands for Energy (kcal), P stands for Protein (g) and L stands for Liquids (mL). CD stands for Comparison Day. For example, for P3W1 the comparison day is one day before the iPad day and for P4W2 the iPad was used the day before the comparison day.
Patient names have been coded because of privacy reasons. P stands for Patient and W for Ward, e.g. P5W3 is Patient 5 in Ward 3. The wards are introduced in section 8.1.
Bold and italic numbers are originating from the iPad application instead of paper registration, since there was no paper information available for these specific users, as explained below.

Some general remarks can be made about table 8.1.

- P1W1: the first patient stopped during testing because of pain complaints. Results of this patient have been discarded.
- P2W1: there are no nutritional records of the comparison day. The day after the iPad usage the patient wasn't allowed to eat, and the day after that the patient was released. There were no other days when the patient's nutritional intake was recorded. Because the day after the iPad usage (and the patient wasn't allowed to eat) doesn't make a fair comparison, this data is not taken into account.
- P3W1: on the comparison day, liquids were not recorded for this patient.
- P5W3: for the iPad day, information from the application has been used because the paper form was clearly not filled in completely.
- P7W3: both nutrition registration papers from the iPad and the comparison day got lost in the ward. Information was also not put in the patient's file. For the iPad day, numbers from the application have been used.

- P8W1: information concerning the liquid intake of the iPad day was on a separate form, which was not retrieved from the ward. Information about energy from liquids (i.e. high density energy drinks) could be retrieved because the energy and protein intake was in the patient's file. The comparison day was two days later, since the day after the experiment, the patient couldn't eat because of a medical examination.
- P10W4: liquid intake of this patient was separately recorded, but not put in the patient's file and the original was already thrown away. High-density energy drinks are therefore also not taken into account for the energy and protein intake. Concerning the comparison day, this seem to be a positive outlier, since the day before the energy intake was only 1154 kcal and 24 gram protein.
- P12W4: the paper form on the iPad day was not filled in completely, and therefore data from the application has been used.

Statistical analysis has been performed with the program SPSS on the data of table 8.1, and showed no significance. The paired-samples t test on energy levels results in t(8)=1,168, p=0,276. Performing statistical analysis on the protein values results in t(8)=-0,187, p=0,856 and the liquid intake is t(5)=0,495, p=0,642. This is all outside the 90% confidence interval, although if it would have been significant that would have meant that the iPad application had a negative impact. Also when excluding the data of P5W3 and P12W4 since these originates from the iPad application and not the paper form, there is still no significance in energy (t(6)=1,330, p=0,232) proteins (t(6)=0,118, p=0,910) nor liquids (t(3)=1,029, p=0,379). The null hypothesis in section 7.5 can therefore not be rejected and it can be concluded that there is no significant change in nutritional intake.

When comparing the intake numbers from the application with the paper forms from the hospital – as displayed in table 8.2 – it can be seen that there are differences. Seven out of eight deltas (the difference between the application data and paper form data) are positive, meaning that the application recorded more intake than the paper form. However, a paired-samples t test showed no significance for energy levels (t(7)=0,506, p=0,628), proteins (t(7)=0,253, p=0,807) nor liquids (t(5)=-0,160, p=0,879).

Table 8.2: Comparing intake from the application to paper forms

	Application data			Paper form data			Delta		
Patient	E	P	L	E	P	L	E	P	L
P2W1	1402	56	1796	1105	43	850	+27%	+30%	+111%
P3W1	3950	172	2315	3824	141	2100	+3%	+22%	+10%
P4W2	2114	67	2374	1277	31	1600	+66%	+116%	+48%
P5W3	1447	43	1723	–	–	–	–	–	–
P6W4	293	12	372	1724	96	2225	-83%	-88%	-83%
P7W3	1735	49	1699	–	–	–	–	–	–
P8W1	1859	66	1612	1300	43	–	+43%	+55%	–
P9W4	1438	54	1076	1390	52	1775	+3%	+4%	-39%
P10W4	1003	17	163	575	16	–	+74%	+6%	–
P11W3	1862	89	1557	1775	84	1350	+5%	+6%	+15%
P12W4	1872	95	2130	–	–	–	–	–	–

8.3 Results of other application data

Information from log messages showed that the social page was not intensively used. Six out of the eleven users looked quickly through it, but only one wrote a message. Further examination of log messages showed that five users used the suggested nutrition buttons in the before meal screen. It could be that they were already planning to consume this, but it could also be that it made them change their mind and tried it out. One user requested help with the press of a button in the application. Six users started the demonstration a second time.

Only three of the users gave a reason for why they consumed less than they should have. Reasons for this were asked after filling in the after meal screen, but since not all patients had problems with eating, this was not applicable to everyone. The users that did answer gave reasons related to their illness (nausea, difficulties eating, swallowing problems, tired, not feeling comfortable, pain) and not the quality of food.

Eight of the eleven users gave a rating to their satisfaction of the food, of which the results are showed in table 8.3. The slider for judging the meal started in the centre with a value from 0,5 and ranged from 0,0 to 1,0. Everything above 0,5 can therefore be valued as positive. Only one of the users wrote a remark below the satisfaction slider.

Table 8.3: Satisfaction rate of meals

	Average	Standard deviation	Number of answers
Breakfast	0,65	0,31	6
Morning break	0,76	0,19	3
Lunch	0,62	0,25	8
Afternoon break	0,77	0,17	5
Dinner	0,76	0,18	7
Evening break	0,49	0,12	3
All meals	0,68	0,24	32

The application calculates the recommended nutritional values based on the user's settings, and compares that to the planned and consumed intake. Information from this and a division per meal is displayed in table 8.4. To keep it organized, only the three most important aspects are shown, which are energy, protein and liquid intake. Planned intake is almost always lower than the consumed intake, which is probably caused by patients using the after meal screen mainly and using the before meal screen less.

Table 8.4: Planned and consumed intake for all patients using the application

	Energy		Proteins		Liquids	
	P	C	P	C	P	C
Breakfast	33%	99%	29%	79%	27%	78%
Morning break	87%	74%	75%	53%	54%	59%
Lunch	83%	80%	80%	91%	50%	55%
Afternoon break	83%	115%	47%	57%	43%	63%
Dinner	59%	106%	62%	114%	31%	59%
Evening break	40%	61%	26%	35%	28%	49%
Total	63%	93%	54%	80%	38%	62%

P stands for Planned and C for Consumed.

Besides the energy, protein and liquids levels, the application recorded also various vitamins and minerals. Figure 8.1 shows these nutritional values with the planned and consumed values compared to the recommended values. These are the averages of all relative numbers from testing persons (i.e. if person A would have a consumption of 90% and person B 60%, the chart would display 75%). It shows relatively high consumption of vitamin B2 (136%), B6 (140%), B12 (191%) and C (138%) and high phosphorus levels (178%).

Although the total consumption for all users is 93% of the recommended, there are large differences between patients. Figure 8.2 shows the planned and

consumed levels of energy, protein, fat, carbohydrate and liquids relative to the recommended values, for the individual users. It can be seen that P3W1 is a positive outlier with up to 276% of the recommended energy consumed, and P6W4 is a negative outlier with only 12% of the recommended energy consumed.

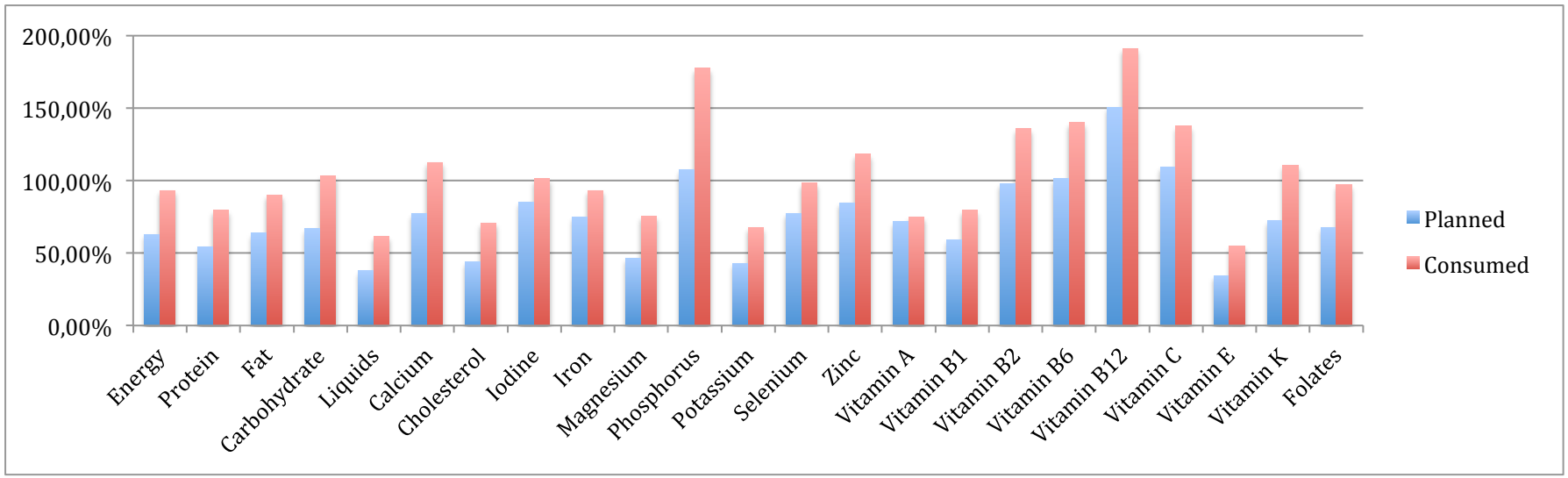

Figure 8.1: Total planned and consumed nutrition relative to recommended

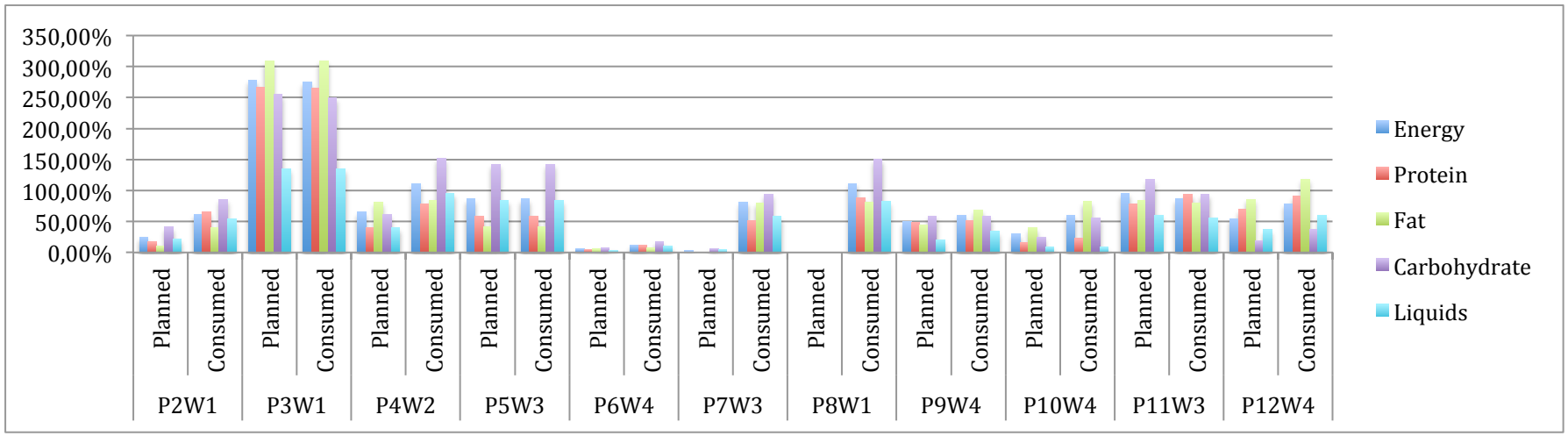

Figure 8.2: Planned and consumed nutrition for individual users

8.4 Results of debriefing

All eleven users filled in the questionnaire (which can be found in appendix A.7), although one person filled in only the questions on the first page and another only the first question. Results of the questionnaire are mentioned in this section, but more details can be found in appendix A.8.

Table 8.5 shows the results of the main part of the questionnaire. Questions one to ten are about the functionality of the application, while the second part of questions 11 to 23 are about the usability. Questions were asked as a statement with a five-point Likert scale as answer (ranging from strongly disagree to strongly agree).

Table 8.5: Responses to closed questions in the questionnaire

		Strongly disagree				Strongly agree
1	Awareness importance nutrition	9%	0%	18%	55%	18%
2	Insight nutritional intake	0%	0%	10%	40%	50%
3	Insight energy needs	0%	10%	10%	70%	10%
4	Like to use more often	10%	0%	20%	40%	30%
5	Useful to use	0%	0%	0%	67%	33%
6	Advices useful	0%	0%	22%	67%	11%
7	Using it improved my intake	0%	11%	22%	56%	11%
8	Improved motivation to eat	0%	22%	11%	44%	22%
9	Increased knowledge nutrition	0%	0%	22%	67%	11%
10	Influenced decision what to eat	0%	13%	25%	25%	38%
11	Satisfied with easiness	0%	0%	22%	56%	22%
12	Confortable using it	11%	0%	11%	56%	22%
13	Easy to learn	11%	0%	22%	33%	33%
14	Clear error messages	29%	14%	29%	14%	14%
15	Easy to recover from mistake	13%	0%	38%	25%	25%
16	Information clear	13%	0%	13%	63%	13%
17	Easy to find information	11%	0%	11%	56%	22%
18	Information easy to understand	0%	0%	0%	78%	22%
19	Organization screens clear	0%	0%	11%	44%	44%
20	Pleasant interface	0%	11%	0%	67%	22%
21	Simple system	11%	0%	0%	67%	22%
22	All functions as expected	0%	13%	13%	50%	25%
23	Overall satisfaction	0%	11%	0%	78%	11%

Besides the 23 questions in the questionnaire, there were also questions about the user. The average age was 56 years (ranging from 20 to 82), with 5 male and six female users. Six users had never tried using a tablet, two tried it a few times, one used it sometimes and two used it weekly. Six patients indicated they have in total been a few weeks in the hospital and five were more "experienced" being in total more than a month. When asked about the time the patient expected to be this time in the hospital, three expected it to be a few days, two a week, four patients believed to be staying a few weeks and one a month.

At the final part of the questionnaire there were also open-ended questions, of which some answers are mentioned here (the complete list can be found in appendix A.8). Negative aspects mentioned were the limited focus on overweight patients, that it takes time to fill in before and after the meal and that there were not so many food options. Positive aspects mentioned were more thinking about what you actually eat when you can see the nutritional values (two people), nice that you can immediately see an overview, the accuracy and clarity, being more aware of energy needs and that it's nice to see the BMI and how much you should eat. About the advice screen was written that it was (really) good, it had easy information, but also that not everything was relevant. With the before meal screen remarks were placed that it was good to think about what you're going to eat, that it gives a good overview of the possibilities, but also that that is difficult since you don't know what to eat before you're going to get it. A user remarked that with the after meal screen it was nice to be able to see what your intake is, and other remarks about the after meal screen were positive. The social screen was often not used (4 times), would not be considered useful (3 times), but someone mentioned the idea and the comparison of food with others was nice.

It has to be mentioned that a disadvantage of using a questionnaire can be that the user may give more positive answers to please the researcher. Especially when talking face-to-face, people tend to give more positive answers (Dahlberg & McCaig, 2010). To limit this somewhat, patients received the questionnaire and a pen during the day they used the iPad and were asked to fill in the questionnaire sometime at the end of 24 hours they used the iPad. The researcher was therefore not present when users filled in the questionnaire, but it was also beneficial for patients since they were often tired, they could fill it in at a time that was suitable for them.

At the end of using the iPad for 24 hours, users where asked if they had any final remarks, and sometimes some additional questions were asked to the patient as a short interview. This resulted in the following remarks:

- P2W1 said the form paper was more difficult to fill in than the iPad application. This had to do with the paper only showing general food options (i.e. lunch small/medium/large) while the application was more specific.
- P6W4 had problems with selecting food after the surgery. It was useful to see the results of selecting food, and to have a list of options.
- For P9W4 it wasn't clear that below the circle diagram in the advice screen the total consumed energy was displayed, but instead thought that the circle itself showed the energy values. After explaining, the patient said that this information is useful and concluded that he didn't eat

enough. Although the patient did remark that he maybe didn't fill it in completely right, which resulted in the suggestion of having an overview with all consumed products for the entire day, as is possible with paper.

8.5 Discussion

There was no significant change in nutritional consumption for patients using the iPad application. There were however more patients consuming less instead of more when using the iPad application than on the comparison day. It has to be remarked that there are possibly long-term effects interfering with the results. Patients having the comparison day before the iPad day seem to have positive or less negative differences (with the exception of P10W4, but that can partly be explained because of the missing liquids); see figure 8.3. Patients having the comparison day after the iPad day have more negative differences (see figure 8.4), which could mean that they've started to consume more after using the application. However, there is not enough data to support this claim.

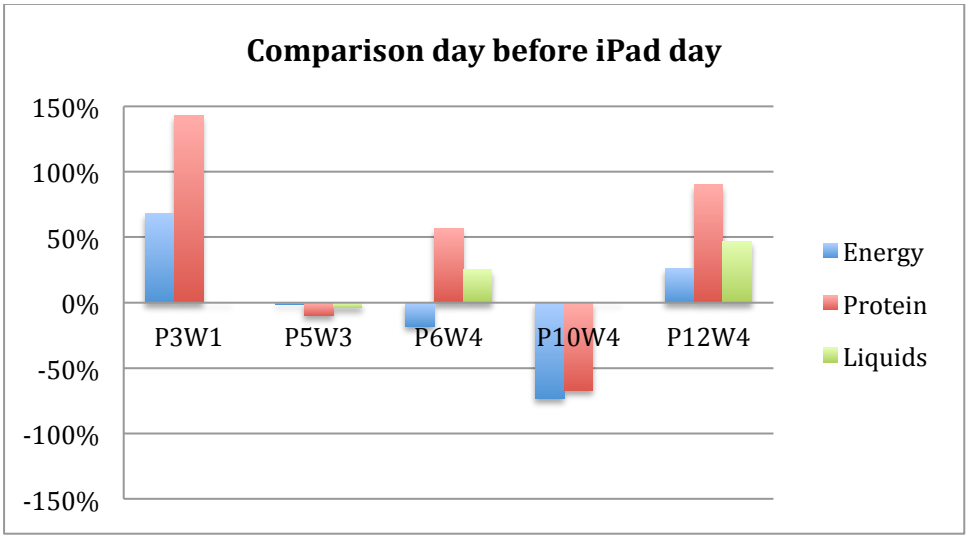

Figure 8.3: Intake change for patients with the comparison day before the iPad day

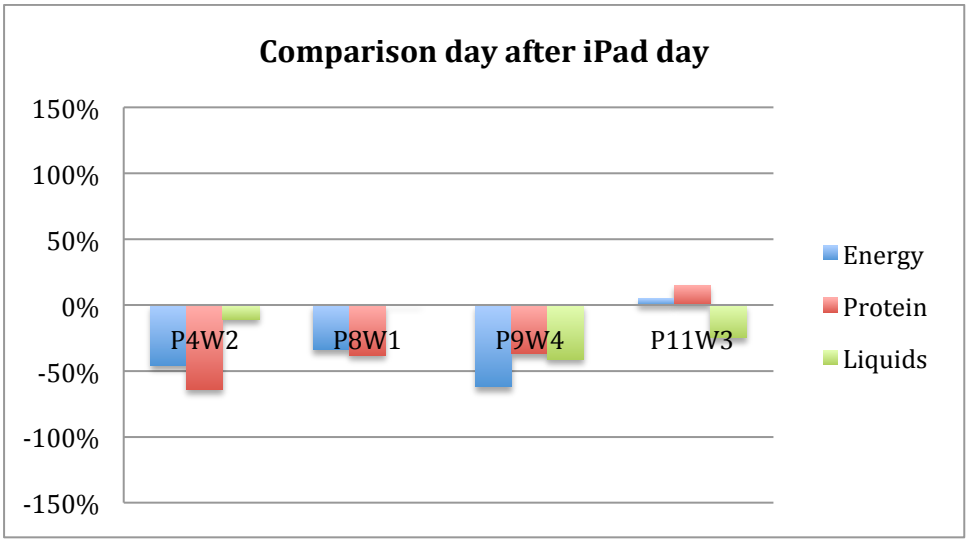

Figure 8.4: Intake change for patients with the comparison day after the iPad day

The information about intake presented in this chapter, and also energy values seen by the researcher in patient's files but not stated in this research, show that there are huge fluctuations. Table 8.1 showed differences between two consecutive days from up to a decline of 73% to an increase of 68% in energy intake. Some fluctuations were expected, but working with numbers as these make it extremely hard to have any significance in the results. Far more testing subjects are needed to be able to prove any effect.

Besides the fluctuation in the numbers from the paper records, the numbers itself are also questionable. When comparing the paper intake with the intake from the iPad application (the delta), there is in seven of eight cases more registered with the application (a positive delta). This might be caused by too high numbers from the application (caused by an error or faulty input from the user), or too low numbers on paper by patients forgetting to register their intake on paper. Regardless of whether the delta is positive or negative, the differences are that high that the accuracy of nutritional recording is questionable.

In practice it was difficult to follow the proposed methodology. Paper forms from the hospital sometimes got lost, which makes it impossible to measure any quantitative changes in the intake. The randomization of using the iPad application the first or second day was in practise also harder to do, although the final division is good with 5 patients having the iPad first and 6 having it the comparison day first. The diversity in wards wasn't mentioned in the methodology, but can be considered positive for the results.

The social page wasn't used much. This had probably to do with that the functionality is different from nutrition registration. Development has also been more focussed on other functionality; where the social section was clearly not real, other functionality was working as it could be used in practise.

There is no indication that there were problems with the quality of the food served. Ratings were overall positive and when asked about reasons for non-consumption, the quality of food wasn't mentioned.

On average 93% of the recommended energy was consumed and 80% of the recommended proteins. However, these numbers don't tell the entire story, since one patient had consumed 276% of the recommended energy levels, while another only 12%. The variation between patients is therefore big. Three out of eleven patients consumed above the recommended, of the remaining 8 were 4 patients undernourished with lower than 70% of the recommended intake.

Overall, the planned values are lower than the actual consumed values. That could be caused by the functionality of the application: when no after meal is put in, but there is a before meal inserted, this before meal is copied to the after meal. It doesn't work the other way, which could explain the lower planned values.

Half of patients (6 out of 11) never used a tablet before. That they were able to input information and use the program is therefore an amazing result. Explaining the application by using a demonstration mode with screenshots probably helped a lot. Also, the users were reassured that they couldn't go outside the program or break something since it had a software lock (a feature in

iOS) that prevented the program from closing; especially with novice users that was reassuring for them.

The questionnaire showed that users were overall satisfied with the application. Most answers were in the box with 4 out of 5 on the Likert scale (meaning fairly agree). Out of 9, 6 users fairly agreed that it was easy to use the program, with 2 strongly agreeing to it and 1 strongly disagreeing. 7 out of 11 found the information from the program fairly easy to understand and 7 out of 9 fairly agreed they were overall satisfied.

With questions about the functionality and persuasion part, 6 became fairly more aware of the importance of nutrition, with 2 strongly agreeing, 1 strongly disagreeing and 2 being neutral. 5 out of 10 strongly agreed that the program gave insight into the nutritional intake and 4 fairly agreed. Regarding the energy needs, 7 out of 10 users fairly agreed that the application gave them more insight. Answers about whether the application influenced the user what to eat were very scattered (although more positive than negative) as was whether the application increased motivation to eat. In total 6 out of 9 fairly agreed that the application was useful for using with the remaining 3 strongly agreeing.

9 Reflection on theoretical foundation

In this entire report, various theories have been discussed and most of them ultimately used for the development of the application. This chapter will evaluate the use of the theories and reflect on their usage. In the first section 9.1 theories concerning the first research question – reasons for malnutrition for hospital patients – will be discussed. Section 9.2 looks back to the persuasive technology theories, how they were used for this research and how useful they were. The last section 9.3 reflects on the development theories, which are the software life cycle and for persuasion the eight step design process.

9.1 Malnutrition reasons

Chapter 2 discussed the causes and solutions of malnutrition in a hospital. It showed the importance to look into this research area, with many patients losing weight during their hospital stay (McWhirter & Pennington, 1994). The study that attempted to educate medical staff did not have the hoped-for effects and showed that it was hard to change nurses' work methods (Lassen, Kruse, Bjerrum, Jensen, & Hermansen, 2004). As explained in chapter 2, this study was one of the reasons for this research not to go on the road of "change management" but to focus on the patients instead. That seemed to be a right decision because during the study it turned out that in practice nurses have almost never time, there were language difficulties and procedures are not always followed.

Various reasons for patients for not consuming enough have been introduced in chapter 2, which were also used in the application. After selecting the nutrition in the application, a small questionnaire asks for reasons of non-consumption (see figure 6.9). Unfortunately, only 3 out of the 11 patients used this functionality in the application and results can therefore not be compared to the theories.

9.2 Persuasive technology theories

In chapter 3 were six persuasion (technology) theories described. These have been used as much as possible with the implementation of the application, although not all theories could be fully applied or had the desired effect. The six theories will now be evaluated one by one.

The first theory of stages of change theory from Prochaska & Norcross (2001) was difficult to implement. Ideally, the system would decide in which phase the patient currently is, and based on that the interface changes. However, dynamic interfaces are difficult to implement and would have taken too much time. It was therefore decided to look at the six different phases and implement something for every phase in the advice screen. That way, all users, although being in different phases, have some interesting elements in the application. Users in the first precontemplation phase are made clear that there is a problem by showing the decrease in weight after a period of time. For patients in the second and third phase (contemplation and preparation) advice texts can be read with tips about improvements. For the third stage (preparation) there is also the possibility to plan all the meals of the day and see the results in the statistics page. When action is taken, the user can record the consumed nutrition and see the results.

For maintenance (fifth stage) it is important to keep using the application and filling in the consumption; relapsing will be made visible by showing the decline in the statistics view. With the final sixth stage (termination) the application is obviously not necessary anymore.

The second theory of cognitive dissonance (Festinger, 1957) is implemented in different ways. Increasing dissonance is attempted by decreasing the attractiveness of not to eat (weight loss section and advice screen showing the consequences) and increasing the importance (textually in the advice screen). A new cognition of trying something new is done by showing the list of nutritional options and textual advice. The consequences of this dissonance is however almost impossible to measure. Another important aspect is that the reward shouldn't be too big, since that would be justification for the change, which doesn't result in long-term change (Benoit & Benoit, 2008). No reward is therefore mentioned in the entire application.

The eight step design process by Fogg (2009a) as the third persuasion theory will be discussed in the next section 9.3.

Many of the 28 persuasion design principles of the fourth persuasion theory from Oinas-Kukkonen & Harjumaa (2008) have been used and applied. This can be seen in the requirements formulation (section 4.3.7). Many of these have also been implemented, as discussed in section 6.9.2. The social principles however proved to be not working, since none of the patients used this intensively. This might be because of the way it was implemented (fictional characters), while the rest of the application showed "real" information. Other principles of e.g. tailoring, simulation, praise and third-party endorsements seem to have the desired effect, or at least no negative effect, given the results of the questionnaire.

The fifth theory of ability, motivation and trigger of Fogg (2009b) showed that little could be improved about the ability of patients to improve nutritional intake. Focus went therefore to motivation, in particular increasing pleasure, hope and social acceptance. The social acceptance was addressed in the social screen, which was however barely used. Increasing pleasure and hope proved to be difficult, especially because of linguistic problems in Danish. The same was true for the trigger, because although triggers were implemented in the form of notifications before and after the meal, making this message motivational was difficult because the researcher didn't master the Danish language. Results from the questionnaire showed that four out of nine patients fairly agreed that the application improved their motivation to eat, two strongly agreed, one patient was neutral and two fairly disagreed.

Finally, the sixth persuasion theories concern messages. Two-sided messages (Perloff, 2010) have especially been applied in additional information texts in the BMI and weight loss section of the advice screen. Because mentioning that the goal is to persuade the user will probably negatively influence the results (Dean, Austin, & Watts, 1971), there is no mention of persuasion. Theories suggest that constraining the personal freedom of the user could result in reactance (Brehm, 1966) and a negative attitude change (Hogg & Vaughan, 2008). Therefore, it is never tried to impose certain nutrition on the patient or limit the choice. The

application supports adding new nutrition options and lets the user choose from an extensive list of nutrition options.

In the end many aspects of the persuasion theories have been applied. However, it is difficult to measure the effect of this. If it had an effect, this should result in improvement of nutritional intake, and therefore the persuasion by itself is almost impossible to measure. Let alone see the effect of individual persuasion theories and elements. It did however provide many ideas for the functionality and it can be assumed that incorporating the theories did not have a negative impact.

9.3 Application realization

There have basically been two theories used for the development of the application; the general software life cycle and the more targeted on persuasion eight step design process. First is the software life cycle from Dix, Finlay, Abowd, & Beale (2004), which is introduced in the introduction of chapter 4. It explains software development as a "waterfall" in a step-by-step way. This procedure has been followed and can be seen in the structure of the report. First step is specifying the requirements, which has been done in chapter 4. Creation of a detailed design have been showed in chapter 5. Implementing (i.e. coding and testing) the application is the next step, which is discussed in chapter 6. Last steps of the waterfall model are integration & testing and maintenance, which are not part of this research.

The software life cycle has also feedback loops to previous steps, because new knowledge obtained later in the process may result in changes to e.g. the requirements or design. Changes in initial knowledge has clearly also been happening in this project. Not all requirements have fully been met (although most of that on purpose) and the final application's design has changed compared to the initial designs. The theory proposes an iterative approach with continued improvements to the prototype. However, because of time limitations this project has had only one iteration. Things learned and feedback received by users should be taken into a second iteration, together with maybe a change in used persuasion theories (e.g. less focus on social), to improve the effectiveness of the application. With a second iteration, requirements should be updated and a new design made based on the current application's design and the new requirements.

The second theory used for the development of the application is stemming from persuasion theories, namely the eight step design process (Fogg, 2009a). It seemed promising in the beginning, however it was difficult to completely follow. The eight steps with their usage are discussed below.

1. *Choose a simple behaviour to target:* the behaviour to target was very much set (namely to improve nutritional intake). Starting with a lower goal has the advantage of higher chances of succeeding, and later on the goal can then be increased. However, for this research there was only time for one development iteration and setting a lower goal would not make much sense (e.g. eating an apple a day).

2. *Choose a receptive audience:* the target audience has not been very limited (see section 7.4 for the target group), which turned out to be good because it was already hard to find patients using the application.
3. *Find what is preventing the target behaviour:* finding out what is preventing target behaviour is done in chapter 2.
4. *Choose an appropriate technology channel:* the chosen technology channel (i.e. iPad application) has been discussed in section 5.1.
5. *Find relevant examples of persuasive technology:* relevant examples of similar techniques have been looked at briefly when designing the application (i.e. nutrition registration applications), but similar applications for in a hospital have not been found.
6. *Imitate successful examples:* because it is to be expected that motivation of hospital patients are different than for healthy people, most persuasion elements of other applications could not be used. Also, most applications are focussed on decreasing nutritional intake, while this project is intending the opposite. For the design however, it was useful to see how nutritional recording applications worked.
7. *Test & iterate quickly:* the application was changed multiple times because of user feedback: a usability study, discussions with employees from the hospital and one patient trying it out. After the experiment started, it was not possible to make changes anymore, since doing that could alter the results.
8. *Expand on success:* this is outside the scope of this research.

Because of the set-up of this research, some steps of the eight step design process could only be partly followed. Simplifying the goal or limiting the target audience probably doesn't give any groundbreaking results. Also step 5 and 6 to look for existing examples was difficult because no comparable application currently exists. For scientific research, this development theory seems therefore be less suitable. It is important in research to not limit the target group or goals too much, nor would it be beneficial to have very similar already existing examples since that would not lead to anything new. This design process seems to be more focussed on practice, where with many small iterations a new innovative product can be designed.

When comparing the two approaches, it can be seen that both work in an iterative way. Although the eight step design process does that a bit different, with steps one to four being set in the beginning and steps five to eight being the iterative steps. The software life cycle starts with a new iteration completely from the beginning again with the requirements. This may lead to much overhead and extra work, but seems to be more suitable for bigger software projects. With the eight step design process it seems inevitable that after time the decisions made in the first four steps don't correspond anymore with the iterative steps five to eight. With the software life cycle being more structured and accurate about the matching of steps, this seems to be more fitting for scientific research than the more practical eight step design process.

An advantage of the eight step design process is the higher focus on persuasion in general. It looks at behaviour of users and other examples of similar persuasive technology. This higher focus on users in combinations with the faster iterations, probably result in finding out earlier what is working well with

users, and what isn't. For the software life cycle this might take a bit longer, since the iterations take longer. However, this is only contemplation, since this project has had only one iteration with the software life cycle, which makes that a comparison between the iteration processes of the theories is not possible.

10 Conclusions

This last chapter is a closing to this research report. First, section 10.1 returns to the original research questions and formulates answers to these. As with any research, also this research has its limitations, which are mentioned in section 10.2. Finally, ideas for future research are discussed in section 10.3.

10.1 Answers to research questions

In section 1.3, three sub research questions were asked:

1. Why do hospital patients have malnutrition and what is being done about it?
2. How can general theories of persuasive technology be adapted for improving nutritional intake of hospital patients?
3. How can a tablet application persuade hospital patients to improve nutritional intake?

These three questions led to the main research question: *Can a tablet application improve hospital patients' nutritional intake?* This section will attempt to answer this.

10.1.1 Malnutrition of hospital patients

As many patients in hospitals are undernourished (up to 43% in the research of Giner, Laviano, Meguid, & Gleason (1996)), chapter 2 discussed reasons and solutions for malnutrition in hospitals. Various reasons for non-consumption were discussed, but no clear reason could be pinpointed as can be expected with a high diversity in patients. Inadequate cooking, taste and mealtime and (partly) the disease or treatment of the patient (Dupertuis, Kossovsky, Kyle, Raguso, Genton, & Pichard, 2003) in combination with a lack of knowledge about menu choices, limitations on available time to eat and disturbance (Lassen, Kruse, & Bjerrum, 2005), the environment the patient is in (Wright, Hickson, & Frost, 2006), the (lack of) company during the meal and other distractions as watching TV (Bellisle & Dalix, 2001) all account for lower consumption.

Studies regarding improvement of the education of hospital staff didn't have the desired effect (Lassen, Kruse, Bjerrum, Jensen, & Hermansen, 2004). A study about increasing the snacks served showed that energy consumption increased, but resulted in high wastage and protein decrease (Gall, Grimble, Reeve, & Thomas, 1998). The possibility of not serving enough food was also dismissed as studies showed that it was served but simply not consumed leading to higher wastage (Barton, Beigg, MacDonald, & Allison, 2000) (Dupertuis, Kossovsky, Kyle, Raguso, Genton, & Pichard, 2003).

Currently, the procedure in Danish hospitals is to monitor and in case of serious undernourishment start with providing fortified nutrition or in worse cases parenteral or tube feeding (Kondrup, Rasmussen, Hamberg, & Stanga, 2003). Parenteral or tube feeding seems to be an effective treatment – in the research of McWhirter & Pennington (1994) 70% of the patients gained weight – but it is an unnatural way of feeding, not pleasant and doesn't solve the original problem of non-consumption.

10.1.2 Persuasive technology for improving nutritional intake

To change behaviour of patients and let them improve the nutritional intake, studies about persuasion were examined in chapter 3. General sociology theories as the six stages of change (Prochaska & Norcross, 2001), cognitive dissonance (Festinger, 1957) and forced compliance (Festinger & Carlsmith, 1959) were discussed, but as an application was going to be developed for improving nutritional intake of hospital patients, focus was mostly on persuasive technology theories. The eight step design process of Fogg (2009a), 28 persuasion design principles from Oinas-Kukkonen & Harjumaa (2008), the concept of ability, motivation and trigger (Fogg, 2009b) and various persuasive message theories are all used in this research. Various ways how these theories can be used in the area of nutritional intake of hospital patients have been discussed.

10.1.3 Persuading hospital patients with a tablet application

The way in which the persuasion theories were used for improving the nutritional intake of hospital patients was described in the functionality chapter (chapter 4) as these theories were incorporated into an iPad application. Details of how a tablet application can persuade hospital patients to improve nutritional intake were presented with the designs of the application in chapter 5. The result of this research question is the iPad application as a prototype, presented in chapter 6.

10.1.4 Improve nutritional intake with a tablet application

To answer the final main research question whether a tablet application can improve nutritional intake, the application was tested in a hospital. Quantitative results of the user study didn't show any significance in the change of nutritional intake. However, qualitative results with a questionnaire and interviews are rather positive. Nine out of ten users fairly or totally agreed that the program gave insight into the nutritional intake and five out of eight fairly or totally agreed that the program influenced them on what to consume. The application also learned most users something: eight out of ten fairly or totally agreed to have gained more insight into energy needs and 7 out of 9 fairly or totally increased its knowledge about nutrition. Regarding their perceived change of intake, results were a bit more scattered, but six out of nine fairly or totally agreed that by using the application nutritional intake was improved and for the same number motivation to eat was improved. All nine respondents fairly or totally agreed that the application is useful. The second part of the questionnaire showed no critical usability problems, with seven out of nine users fairly or strongly agreeing to feeling comfortable using the application, which was important since half of the patients (6 out of 11) indicated to never have used a tablet before.

10.2 Limitations

There were limitations on what could be done in the given timeframe for this research project. Concerning the used theories of malnutrition and persuasion, a complete literature review couldn't be done. The areas of nutrition and persuasion are a large research field of their own and a literature study would

take too much time. Therefore there is simply no guarantee that some solutions for undernourishment or useful persuasion theories might have been missed during the literature search.

The persuasion theories used in this research were implemented as much as possible in the application. It could be that some theories might not work in the situation, or even counter-balance other theories. However, it is hard to measure how much certain individual persuasion theories – or in general persuasion as a whole – has an effect. To measure this, different versions of applications should be developed to be able to compare differences in persuasion theories. However, testing the different persuasion theories was not the intent of this research and requires a different methodology. It requires probably more lab-testing or "fake" patients instead of real-world testing (which is done in this research), since comparing different versions requires many users which is difficult to realize in real-world testing.

There were also limitations in the area of testing the application. Only one hospital was used, although with four different wards. The number of users that tried out the application was limited, users were only of Danish nationality and were within a certain target group (see section 7.4). However, considering the limited timeframe and that the experiment was a real-world test and not lab-testing, limitations as these are quite common.

10.3 Future research

Finding patients volunteering for this research proved to be difficult and time-consuming and therefore only eleven users were found. Future research could increase the number of testing users, because for being able to have quantitative results, it is necessary to have more users. This can be done by decreasing the target group exclusion criteria and/or making the testing procedure easier. On the other hand, for this research the application was tested for 24 hours, but that could coincidentally be a bad day for the patient or the patient may not like the food of that day. Testing the application over more days could lead to other interesting insights.

Longer testing the application could also show long-term effects. Results suggested that patients with the comparison day after the iPad day started to consume more than patients with the comparison day before the iPad day. This could be caused by the patients following the advice of the application to increase nutritional intake. Further research could test this, but would have to filter out the effects of the patient getting better over time.

Various future directions can be taken in the area of this research. When considering the literature used, more or other theories could improve the effectiveness. This can be in the field of persuasion (technology) or more general sociology, but other research fields can also be considered. The focus of this research has been on testing the application in real-life with hospital patients, and because of that it was not possible to compare the effectiveness of individual persuasive elements. Another research methodology for testing the persuasive elements could help improving the effectiveness of the application.

When further developing the application, which is basically starting up a second iteration of the software life cycle, it should be made clear what the functionality

should be. The social section was in the end differentiated from the rest of the application (which was probably not positive for the use of it) and could either be better integrated with the rest or completely removed. Other functionality as monitoring for nurses and making a picture of the plate instead of selecting the food have been dropped with this research, but can be a good addition to the application. Supporting more devices than just the iPad would also benefit the number of potential users, since many patients were seen with a smartphone, tablet or laptop.

For future experiments it is good to consider possibilities to lower the number of variables in the research. There was high fluctuation in the nutritional numbers of patients between days. These high fluctuations make it difficult to prove that something is significant. Data from this research also suggests that the application recorded more nutrition than on paper. The reliability of paper registration in the hospital should therefore be taken into consideration.

For half of the users in the hospital it was the first time they used a tablet; they were however very well able to use the application. Given the growing popularity of tablets and wider availability, using tablets in the hospital for patients seems to be a logical step forward. Using applications for this is an ideal situation in which patients can use it themselves, while nurses don't have to spend time on it but could have benefits as e.g. (better) monitoring possibilities. Applications that can help patients offer opportunities that hospitals didn't have before. This research has shown that improving nutritional intake of hospital patients by using a persuasive tablet application has promising possibilities.

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Appendices

A.1 Usability testing consent form

The consent form below has been given to participants in the usability testing, as discussed in section 5.3. The text is based on the template of (User Experience Group - Indiana University, 2005).

Participant consent form

The purpose of this usability study is to evaluate the design of the nutritional application. We are interested in determining if people can accomplish common tasks and easily find information using this application. The session will not 'test' you or your ability, rather the session will test the application to provide information on areas that might be improved. Please be advised that there are no risks associated with participation in this session.

During this session, you will be asked to complete some tasks using the application. The application is intended for patients in a hospital and tracks their nutritional (food and drinks) intake. Afterwards, you will be asked to fill out a user satisfaction questionnaire. As you complete the tasks, someone will observe and take notes. In addition, the session will be captured on video for future review. The session will last no longer than twenty minutes.

If for any reason you are uncomfortable during the session and do not want to complete a task, you may say so and we will move on to the next task. In addition, if you do not want to continue, you may end the session and leave at any time.

Approximately 7 people will participate in this study. Results from all sessions will be included in a usability report. Your name will not be included in the report nor will your name be associated with any session data collected.

I, _____, have read and fully understand the extent of the study and any risks involved. All of my questions, if any, have been answered to my satisfaction. My signature below acknowledges my understanding of the information provided in this form and indicates my willingness to participate in this user testing session. I have been given a blank copy of this consent form for my records.

Signature:_____ Date:_____

A.2 Usability testing questionnaire

This questionnaire is used for the usability testing, as explained in section 5.3. First, four general questions are asked. Then usability questions are asked, which is a selection of (Lewis, 1995), with non-relevant questions removed from the original list. Participants have to answer on a 5-points scale, which goes from strongly disagree to strongly agree. Participants are encouraged to make remarks about every question. Closing questions offer the possibility to mention negative and positive aspects about the application.

What is your age?	**…… years**
Are you	**☐ Male** **☐ Female**
How experienced are you using a tablet computer (e.g. iPad, Samsung Galaxy Tab or Sony Tablet S; NOT an e-reader as Amazon Kindle or the Barnes & Noble Nook)	**☐ Never** **☐ Tried it out a few times** **☐ Thinking about buying one** **☐ Owning one/more and using it sometimes** **☐ Owning one/more and using it weekly** **☐ Owning one/more and using it daily**
How many days have you in total stayed in a hospital overnight as a patient during your entire life?	**☐ Never** **☐ Few days** **☐ Week** **☐ Month** **☐ More than a month**

	Strongly disagree				**Strongly agree**
1. Overall, I am satisfied with how easy it is to use this system.					
Remarks:					
2. It is simple to use this system.					
Remarks:					
3. I feel comfortable using this system.					
Remarks:					
4. It was easy to learn to use this system.					
Remarks:					

5. Whenever I make a mistake using the system, I recover easily and quickly.					
Remarks:					
6. It is easy to find the information I need.					
Remarks:					
7. The information provided with the system is easy to understand.					
Remarks:					
8. The organization of information on the system screens is clear.					
Remarks:					
9. The interface of this system is pleasant.					
Remarks:					
10. I like using the interface of this system.					
Remarks:					
11. This system has all the functions and capabilities I expect it to have.					
Remarks:					
12. Overall, I am satisfied with this system.					
Remarks:					

Please list the most **negative** aspect(s):

……

……

……

Please list the most **positive** aspect(s):

……

……

……

A.3 Results usability testing questionnaire

Six participants filled in the questionnaire from appendix A.2. Answers to the questionnaire are given below in the same template as the questionnaire itself. Options that weren't used in the 18 usability questions table are left empty to improve readability, but can be read as "0 – 0%". Discussion of the results is done in section 0.

What is your age?	**18, 22, 24, 24, 54 & 59 years**
Are you	**3 (50%) Male** **3 (50%) Female**
How experienced are you using a tablet computer (e.g. iPad, Samsung Galaxy Tab or Sony Tablet S; NOT an e-reader as Amazon Kindle or the Barnes & Noble Nook)	**2 (33%) Never** **2 (33%) Tried it out a few times** **0 (0%) Thinking about buying one** **0 (0%) Owning one/more and using it sometimes** **0 (0%) Owning one/more and using it weekly** **2 (33%) Owning one/more and using it daily**
How many days have you in total stayed in a hospital overnight as a patient during your entire life?	**3 (50%) Never** **2 (33%) Few days** **1 (17%) Week** **0 (0%) Month** **0 (0%) More than a month**

	Strongly disagree				**Strongly agree**
1. Overall, I am satisfied with how easy it is to use this system.		1 17%	1 17%	4 67%	
Remarks: selecting of pancakes difficult to find					
2. It is simple to use this system.			1 17%	5 83%	
Remarks: use icons + text					
3. I feel comfortable using this system.			1 17%	3 50%	2 33%
Remarks:					
4. It was easy to learn to use this system.				5 83%	1 17%
Remarks:					
5. Whenever I make a mistake using the system, I recover easily and quickly.				3 60%	2 40%
Remarks: not tested					

6. It is easy to find the information I need.			2 33%	3 50%	1 17%
Remarks:					
7. The information provided with the system is easy to understand.		1 17%	1 17%	3 50%	1 17%
Remarks:					
8. The organization of information on the system screens is clear.			2 33%	4 67%	
Remarks: "social" not clear					
9. The interface of this system is pleasant.				5 83%	1 17%
Remarks: the should be less information on a page					
10. I like using the interface of this system.				5 83%	1 17%
Remarks:					
11. This system has all the functions and capabilities I expect it to have.			1 20%	3 60%	1 20%
Remarks: don't know. Possibly add headlines news, weather forecast, icons for food					
12. Overall, I am satisfied with this system.				5 83%	1 17%
Remarks:					

Please list the most **negative** aspect(s):

- Could not find a back button
- More interaction: the information you see should depend on the answer you gave

Please list the most **positive** aspect(s):

- Providing good advise on what else I can eat
- Simple design
- Once you know how the program works, it is easy to use
- Like the layout

A.4 Changes after testing with first hospital patient

Section 6.7 explains that the application was tested with one patient in the hospital. This resulted in the following ten changes to the application.

- The list of possible nutrition options was long and it was therefore sometimes hard to find a product. It was changed that, depending on the meal selected, some categories won't be displayed (e.g. when breakfast is selected, lunch and dinner options are not in the list). Furthermore, when selecting a different meal, the list is automatically scrolled to the nutrition options that belong to that meal.
- There were difficulties with the slider to set the amount of nutrition. The user appeared to be trying to set a certain amount, but since slight changes in sliding resulted in big value changes, this was difficult. It was decided to change the slider's upper value from 10 to 5 to make the slider less sensitive.
- In the cell to select the amount of nutrition (e.g. 1,2 portion or 0,7 cup), it now also displays the amount of gram selected. However, for drinks it was remarked that this should be in millilitres. Because the database doesn't contain information whether it is fluid or solid food, the text to display the amount is changed from "grams" to "grams/mL".
- Having a save button in the after meal screen, but not in the before meal screen was inconsistent. Furthermore, the user didn't know what to do after selecting the nutrition items in the before meal screen and so actually expected a save button. Although technically unnecessary, a save button has been added to the before meal screen.
- The buttons of making a picture of the plate were unclear, and a text was added above the button to clarify that making a picture is optional and has to be done before and after eating (to be able to calculate the amount consumed and left over).
- All notification alerts (i.e. 15, 10, 5 and 0 minutes before and after the meal) had an audio cue to request the user to fill in the information. This was however experienced a bit annoying, also because of the volume of this audio cue couldn't be turned lower. The audio cue was turned off for all notification alerts except for the 15 minutes before and after the meal; other notifications are only visually displayed.
- Certain buttons in the application trigger a popover (e.g. the "change meal" button or "more information"). Normal behaviour is that by tapping the button again another popover will be opened. This seemed confusing behaviour and therefore it was implemented in the application that the button was disabled when the popover was open; closing the popover could be done by tapping anywhere on the screen. However, the user tried to close the popover by tapping the button again and was confused when this didn't work. The button was therefore re-enabled again, but was set-up in such a way that tapping it closed the popover instead of opening another one.
- Meal times of the ward were set up correctly.
- The log functionality was expanded with more log messages to better see afterwards which actions the user took.

- When using the database of the application and convert it to the MySQL database and Excel file (as described in section 6.5), it appeared that there were inconsistencies. Suggested protein and carbohydrate recommendations didn't match, which was caused by the transformation of energy amounts from kJ to kcal. This bug was fixed in the application.

A.5 User study consent form

The consent form and additional information form below has been given to participants in the user study, as discussed in section 7.7. The consent form is in Danish, and is a template from the ethical committee from Aalborg hospital. The text of the "additional information for participant consent form" is based on the template of the Psychology Department of Harvard University (2012).

(S3)

Informeret samtykke til deltagelse i et biomedicinsk forskningsprojekt.

Forskningsprojektets titel: iPad Kostregistrering- udviklingsprojekt

Erklæring fra forsøgspersonen:

Jeg har fået skriftlig og mundtlig information og jeg ved nok om formål, metode, fordele og ulemper til at sige ja til at deltage.

Jeg ved, at det er frivilligt at deltage, og at jeg altid kan trække mit samtykke tilbage uden at miste mine nuværende eller fremtidige rettigheder til behandling.

Jeg giver samtykke til, at deltage i forskningsprojektet. Jeg har fået en kopi af den skriftlige information om projektet til eget brug.

Forsøgspersonens navn: _____

Dato: _____ Underskrift: _____

Ønsker du at blive informeret om forskningsprojektets resultat (på engelsk)?:

Ja _____ (sæt x) Nej _____ (sæt x)

Erklæring fra den forsøgsansvarlige:

Jeg erklærer, at forsøgspersonen har modtaget mundtlig og skriftlig information om forsøget.

Efter min overbevisning er der givet tilstrækkelig information til, at der kan træffes beslutning om deltagelse i forsøget.

Den forsøgsansvarliges navn: Sjoerd Smink

Dato: _____ Underskrift: _____

Additional information for participant consent form

Purpose of the research: To examine the nutritional intake (food and drinks) of hospital patients.

What you will do in this research: You will have to record your expected and actual nutritional intake for 24 hours. For this you use the application created for this experiment. The application will be explained to you in the beginning of the experiment. You are free (and actually encouraged) to use all the functions of the application.

Time required: Participation will take approximately 60-90 minutes in total. The experiment will run for 24 hours.

Risks: There are no anticipated risks associated with participating in this study. The system will give nutritional advice. Although this advice is composed in the best possible way, and you are encouraged to follow and use the nutritional advice, it is still based on a computer model. Always listen to doctors, nurses, dieticians and common sense first, and do not act on the advice of the application blindly. The application gives you an advice, not an order.

Benefits: At the end of the study, we will provide a thorough explanation of the study and of our hypotheses. We will describe the potential implications of the results of the study both if our hypotheses are supported and if they are disconfirmed. If you wish, you can send an email message to sjoerd smink @ gmai l.com and we will send you a copy of any manuscripts based on the research (or summaries of our results).

Compensation: You will receive no monetary reward for participating in this study, since there is no budget for this project.

Confidentiality: Your participation in this study will remain confidential, and your identity nor hospital data will not be stored with your data. Your participation in this study will remain confidential and there will be no link between your responses and your identity.

Participation and withdrawal: Your participation in this study is completely voluntary, and you may withdraw at any time without penalty. You may withdraw by informing the researcher that you no longer wish to participate (no questions will be asked).

How to contact the researchers: If you have questions or concerns about your participation or payment, or want to request a summary of research findings, please contact the researcher: Sjoerd Smink, sjoerd smink @ gmai l.com, 81922229. For any other problems related to this study, you may also contact the faculty member supervising this work: Jan Stage, jan s@c s.aau.dk.

A.6 User study debriefing

The debriefing form below has been given to participants after the user study, as discussed in sections 7.6. The text is based on a template of the Psychology Department of Harvard University (2012).

Participant debriefing

This study is concerned with the nutritional intake of hospital patients. Various studies have shown that malnutrition is common in hospitals and affect the recovery of patient negatively. Using a tablet application, patients could be persuaded to improve nutritional intake.

How is this being tested?

In this study, your nutritional intake was recorded for 48 hours by nurses or yourself. The nutritional intake of the 24 hours you were using the iPad application is compared to the nutritional intake of the 24 hours you weren't using the iPad application. There are two participant groups, you could have been in either one of them because the assignment of it was done at random. One group uses the application the first day and not the second, whereas the other group doesn't use the application the first day but does use it the second.

Hypothesis and main questions:

It is expected to find that patients using the iPad application have improved nutritional intake. The application should provide advice for and insight into the nutritional intake and thereby persuading the patient to improve their intake. Whether the nutritional intake is improved, is examined by looking at the total energy intake, division of energy elements (proteins, carbohydrates and fats), vitamins and minerals.

Why is this important to study?

Undernourishment is common in hospitals and causes longer recovery times. This is not good for the patient, but also results to higher healthcare costs for society. Nurses have limited time to support and advice patients concerning nutrition, and dieticians are scarce in the hospital. An iPad (or other tablet) application doesn't require time from nurses or dieticians, and are relatively cheap.

How to contact the researcher: If you have questions or concerns about your participation, or want to request a summary of research findings, please contact the researcher: Sjoerd Smink, sjoerd smink @ gmai l.com, 8192 2229. For any other problems related to this study, you may also contact the faculty member supervising this work: Jan Stage, jan s@c s.aau.dk.

Thank you for your participation!

A.7 User study questionnaire

The questionnaire below has been given to participants in the user study, as discussed in section 7.6. The questionnaire is in Danish, the English translation – together with the results – can be found in appendix A.8.

Hvor gammel er du?	**…… år**
Køn	☐ **Mand** ☐ **Kvinde**
Hvor erfaren er du med en tablet computer (f.eks. iPad, Samsung Galaxy Tab eller Sony Tablet S; IKKE en e-reader som Amazon Kindle)	☐ **Aldrig prøvet at bruge en** ☐ **Prøvet det et par gange** ☐ **Har en/flere og bruger den til tider** ☐ **Har en/flere og bruger den ugentlig** ☐ **Har en/flere og bruger den daglig**
Hvis du tænker på alle de gange du har vært indlagt som patient på et hospital igennem hele dit liv, hvor mange dage har du så i alt været indlagt?	☐ **Få dage** ☐ **En uge** ☐ **Få uger** ☐ **Måned** ☐ **Mere end en måned**
Hvor længe tror du, at du skal vær indlagt i forbindelse med DETTE ophold?	☐ **Få dage** ☐ **En uge** ☐ **Få uger** ☐ **Måned** ☐ **Mere end en måned**

Sæt ét kryds

	Stærkt uenig				**Meget enig**
1. Programmet har gjort mig mere bevidst om betydningen af ernæring.					
Bemærkninger:					
2. Jeg synes, at programmet har givet mig indblik i mit ernæringsmæssige indtag.					
Bemærkninger:					

	Stærkt uenig				Meget enig
3. Jeg synes, at programmet har givet mig indsigt i mit energibehov.					
Bemærkninger:					
4. Jeg vil gerne bruge dette program oftere					
Bemærkninger:					
5. Jeg synes, det er nyttigt at bruge programmet.					
Bemærkninger:					
6. De råd jeg fik fra programmet var nyttige.					
Bemærkninger:					
7. Jeg synes, at ved at bruge dette program, har jeg forbedret mit ernæringsmæssige indtag.					
Bemærkninger:					
8. Programmet øgede min motivation til at spise.					
Bemærkninger:					
9. Programmet har øget min viden om ernæring.					
Bemærkninger:					
10. Programmet har påvirket min beslutning om, hvad jeg skal spise.					
Bemærkninger:					
11. Samlet set er jeg tilfreds med, hvor nemt det er at bruge dette program.					
Bemærkninger:					
12. Jeg føler mig tryg ved at bruge dette program.					
Bemærkninger:					
13. Det var let at lære, at bruge dette program.					
Bemærkninger:					

	Stærkt uenig				Meget enig
14. Programmet giver fejlmeddelelser, der tydeligt fortæller mig, hvordan jeg løser problemer.					
Bemærkninger:					
15. Når jeg laver en fejl i brugen af programmet, finder jeg hurtigt og nemt tilbage til udgangspunktet.					
Bemærkninger:					
16. De oplysninger jeg får fra programmet (f.eks. hjælp, beskeder på skærmen og anden dokumentation) er tydelige og lette at forstå.					
Bemærkninger:					
17. Det er nemt at finde de oplysninger, jeg har brug for.					
Bemærkninger:					
18. De oplysninger, der følger med programmet er lette at forstå.					
Bemærkninger:					
19. Organiseringen af information på programmets skærm er klar og nem at forstå.					
Bemærkninger:					
20. Jeg kan godt lide programmets grafiske brugergrænseflade.					
Bemærkninger:					
21. Det er simpelt at bruge dette program.					
Bemærkninger:					
22. Dette program har alle de funktioner og kapaciteter jeg forventer det skal have.					
Bemærkninger:					
23. Samlet set er jeg tilfreds med dette program.					
Bemærkninger:					

Angiv venligst mest negative aspekt(er) ved at bruge programmet:

……

……

……

Angiv venligst mest positive aspekt(er) ved at bruge programmet:

……

……

……

Hvad synes du om de råd skærmen (med rådgivning tekster og diagrammer)?

……

……

……

Hvad synes du om at angive oplysninger om dit forventede indtag før måltidet?

……

……

……

Hvad synes du om at angive oplysninger om dit faktiske indtag efter måltidet?

……

……

……

Hvad synes du om den del af programmet der giver dig mulighed for at chatte med andre?

……

……

……

Hvis du har andre bemærkninger, bedes du angive dem her:

……

……

……

A.8 Results user study questionnaire

Below are the results of the questionnaire from appendix A.7, filled in by eleven users. Given remarks were originally in Danish, but here translated to English. The results are discussed in section 8.4.

What is your age?	**Average 56 years (20, 23, 39, 57, 57, 61, 68, 68, 69, 70 & 82)**
Gender	**5 (45%) Male** **6 (55%) Female**
How experienced are you with a tablet computer (e.g. iPad, Samsung Galaxy Tab or Sony Tablet S; NOT an e-reader as Amazon Kindle)	**6 (55%) Never tried using one** **2 (18%) Tried it out a few times** **1 (9%) Owning one/more and using it sometimes** **2 (18%) Owning one/more and using it weekly** **0 (0%) Owning one/more and using it daily**
When you think about all the times you were as a patient in the hospital in your entire life, how many days have you in total been hospitalized?	**0 (0%) Few days** **0 (0%) Week** **6 (55%) Few weeks** **0 (0%) Month** **5 (45%) More than a month**
How long are you (probably) staying in the hospital this time?	**3 (30%) Few days** **2 (20%) Week** **4 (40%) Few weeks** **1 (10%) Month** **0 (0%) More than a month**

	Strongly disagree				**Strongly agree**
1. The system has made me more aware of the importance of nutrition.	1 9%	0 0%	2 18%	6 55%	2 18%
Remarks:					
2. I feel the system has given me insight into my nutritional intake.	0 0%	0 0%	1 10%	4 40%	5 50%
Remarks:					
3. I feel the system has given me insight into my energy needs.	0 0%	1 10%	1 10%	7 70%	1 10%
Remarks: just a bit late in my hospital stay					
4. I would like to use this system more often.	1 10%	0 0%	2 20%	4 40%	3 30%
Remarks:					

	Strongly disagree				Strongly agree
5. I found it useful to use the application.	0 0%	0 0%	0 0%	6 67%	3 33%
Remarks:					
6. The advices from the system were useful.	0 0%	0 0%	2 22%	6 67%	1 11%
Remarks:					
7. I believe that using this system I improved my nutritional intake.	0 0%	1 11%	2 22%	5 56%	1 11%
Remarks:					
8. The system improved my motivation to eat.	0 0%	2 22%	1 11%	4 44%	2 22%
Remarks: already overweight, ate too much according to program					
9. The system increased my knowledge about nutrition.	0 0%	0 0%	2 22%	6 67%	1 11%
Remarks:					
10. The system influenced my decision on what to consume.	0 0%	1 13%	2 25%	2 25%	3 38%
Remarks:					
11. Overall, I am satisfied with how easy it is to use this system.	0 0%	0 0%	2 22%	5 56%	2 22%
Remarks:					
12. I feel comfortable using this system.	1 11%	0 0%	1 11%	5 56%	2 22%
Remarks:					
13. It was easy to learn to use this system.	1 11%	0 0%	2 22%	3 33%	3 33%
Remarks:					
14. The system gives error messages that clearly tell me how to fix problems.	2 29%	1 14%	2 29%	1 14%	1 14%
Remarks:					
15. Whenever I make a mistake using the system, I recover easily and quickly.	1 13%	0 0%	3 38%	2 25%	2 25%
Remarks: haven't tried					

	Strongly disagree				**Strongly agree**
16. The information (such as help, on-screen messages and other documentation) provided with this system is clear.	1 13%	0 0%	1 13%	5 63%	1 13%
Remarks: haven't used					
17. It is easy to find the information I need.	1 11%	0 0%	1 11%	5 56%	2 22%
Remarks:					
18. The information provided with the system is easy to understand.	0 0%	0 0%	0 0%	7 78%	2 22%
Remarks:					
19. The organization of information on the system screens is clear.	0 0%	0 0%	1 11%	4 44%	4 44%
Remarks:					
20. The interface of this system is pleasant.	0 0%	1 11%	0 0%	6 67%	2 22%
Remarks:					
21. It is simple to use this system.	1 11%	0 0%	0 0%	6 67%	2 22%
Remarks: Not so much					
22. This system has all the functions and capabilities I expect it to have.	0 0%	1 13%	1 13%	4 50%	2 25%
Remarks: Not so much					
23. Overall, I am satisfied with this system.	0 0%	1 11%	0 0%	7 78%	1 11%
Remarks:					

Please list the most negative aspect(s) of using the program:

- Currently not designed for overweight people, which would be nice.
- To achieve the recommended amounts, I ate so much that it was uncomfortable. I'm not used to such high fat foods, so it caused a little discomfort.
- It takes time to fill in before and after.
- There are not so many food options in the list.

Please list the most positive aspect(s) of using the program:

- Gives you a good insight on what you eat and what it contains (2 times).
- It is nice to be able to see a list with intake.
- Awareness.
- The accuracy and clarity. And avoiding manual calculations.
- You become aware of your energy needs. It is nice to see your BMI and how much you should eat.

What do you think about the advice screen (with the advice texts and charts)?

- Ok.
- Performed well.
- Really good, easy information.
- Good, but not everything was relevant.

What do you think about the entering of information about your estimated intake before the meal?

- Really good.
- Ok.
- Really good and clear.
- A good idea.
- Good.
- Very good for giving inspiration and an overview.
- It is difficult, because I don't know what I'll eat before I get it.
- It made me think about what I actually wanted to eat.

What do you think about the entering of information about your actual intake after the meal?

- Really good.
- Ok (2 times).
- Good (2 times).
- Performed well.
- Nice.
- It was okay, and fun to see what your intake is.

What do you think about the part of the program that gives you the possibility to chat with others?

- Not useful for me (3 times).
- Haven't tried (2 times).
- Haven't used.
- Don't know.
- Haven't tried, but looked at it, and I like the idea and to be able to see what others have eaten.

If you have any other remarks, please state them here:

- Program should work for all kinds of patients.
- Generally good.
- Don't know the program well enough to comment on the above.