A social robot as a means to motivate and support diabetic children in keeping a diary

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Abstract

This study is part of the European FP7 ALIZ-E project. The goal of this project is to develop the theory and practice behind an embodied social robot that is capable of maintaining affective interactions with young users over an extended and possibly discontinuous period of time. The target audience of this research consists of young patients suffering from diabetes mellitus. In previous work on ALIZ-E, several activities have been developed that the user can carry out with the robot, such as playing a quiz, math game or imitation game. Research has shown that monitoring one's diabetes by keeping a diary is beneficial to the child's health on the short and long term. In this master thesis, we develop a new activity that allows a diabetic child to keep an online diabetes diary together with the robot. We evaluate this new activity by investigating the following research question:

How can a robot contribute to the activity of keeping a web-based diary together with diabetic children?

We present a comprehensive robot dialogue model that has two main foci: 1) supporting and motivating the child in the task of keeping a diary and 2) forming a bond between the child and the robot through personalized interaction. We tested the dialogue model by performing a pilot experiment in a real-world setting using a within-subjects design (N=6). The subjects were diabetic children between the ages of 9 to 12. Over the course of eleven days, they kept an online diary in which they logged their blood glucose values, carbohydrate intake, insulin dosages, exercise, emotional well-being and their daily activities. Every other day the children remotely connected to the robot, which they believed to be autonomous, and performed this activity together. The robot provided explanations where necessary; asked the child relevant questions and shared personal information to establish a social bond. We measured adherence by comparing the frequency of diary entries and the diary content between the two conditions. Engagement was measured by observing the children's participation and attention during the interactions. We used a questionnaire and observations made during the experiment as indicators for the development of a bond between the robot and the child.

The results show that low diary adherence is a common problem among diabetic children. We showed that interacting with the robot while keeping a diary helped to improve adherence. Children had significantly more completed diary entries with the robot present than while the robot was absent. Overall, both the diary and the robot were rated quite positively. Children felt the robot supported them well in performing the task, and they thought the robot was friendly, trustworthy and human-like. The children openly shared information with the robot about their daily lives, and were very inquisitive about the robot's life as well. This was also explicit in their diaries, where we found a significantly larger amount of information shared in the diaries on days with the robot. The children eventually came to see the robot as a friend.

We need to be careful in saying the results we found are solely the result of our intervention. But we do think that using a robot can greatly enhance the pleasure of the activity and therefore the motivation of the child. Keeping a diary with the support from a robot can help the children take the next step in taking responsibility for their own self-management.

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Contents

1 Introduction

Imagine the following situation:

> *"You are a 6-year-old child. You just learned how to read and write, and you have some basic math skills. Lately you have been feeling thirsty all the time and losing body weight for no apparent reason. When your parents decide to take you to see the doctor, he tells you that you have diabetes type 1. You do not understand what this means, but from your parents' reactions you know it is serious. You are then admitted to the hospital for one or two weeks where you and your parents are intensively educated and trained to manage your diabetes. You learn about counting carbohydrates, how to measure your blood glucose and how to prick insulin. It is a stressful period, but everyone works together to help you get through it. A few years pass, and you begin to realize that your diabetes is not going to go away. Your parents want you to start taking on more responsibilities for your own care. You struggle with this increased responsibility; you just want to feel normal like everyone else."*

Diabetes is a chronic illness that impacts a child's life in almost every aspect. Children frequently have trouble coping with their diabetes (Geist, 1979; Tarnow & Tomlinson, 1978; Wishner & O'Brien, 1978; Sullivan-Bolyai, Deatrick, Gruppuso, Tamborlane & Grey, 2003; Whittemore, Kanner & Grey, 2004). They are at increased risk for developing depression, anxiety disorders or eating disorders (Grey, Whittemore & Tamborlane, 2002; Kovacs, Goldston, Obrosky, & Bonar, 1997; Affenito & Adams, 2001; Polonsky, Anderson, Lohrer, Aponte, Jacobson & Cole, 1994). When they reach puberty they often rebel against their parents' authority and fail to adhere to their treatment regimens (Lask, 2003). Health care practitioners advise children to keep a record of their blood glucose levels in a diabetes diary so that they can make adjustments to their treatment. However, keeping a diary is problematic, not just for children, but for diabetes patients in general (Gonder-Frederick, Julian, Cox, Clarke & Carter, 1988; Robertson, 2012). There is evidence that an online digital diary yields much better adherence results than the traditional paper diary that is currently provided to diabetes patients (Burke et al., 2012; Palermo, Valenzuela & Stork, 2004; Jamison et al., 2001). But these online diaries are all aimed at the adult audience. They are plain, boring, formal and purely functional and so they are hardly interesting to children. We need a different approach to motivate and support these children in keeping their diaries.

In June 2012 we hosted a focus group in a Dutch hospital for diabetic children to discuss their use of a diabetes diary with us. None of the children kept such a diary. They did not care for it, nor did they see the value (yet) in keeping a paper record of their blood glucose values. Their parents often took responsibility for recording values, but they often only did so a few days before a doctor's appointment. Once the doctor's visit was over, they once again neglected to keep a record. The children all had large stacks of diaries at home, but they were rarely being used. When we proposed the idea to have a robot help them keep a digital diary, the children were enthusiastic. They were particularly interested in learning more about the robot's capabilities and its personal background[1]. And so the idea to use a social robot to motivate and support diabetic children in keeping a diary came into being.

[1] The full summary of the focus group can be found in Appendix E.

1.1 ALIZ-E

This study is part of the European FP7 ALIZ-E project, which aims to develop novel methods for developing and testing interactive, mobile robots which will be able to socially interact with human users over extended periods of time (ALIZ-E, 2009). The project specifically explores child-robot interaction using Aldebaran Robotics' robot NAO. NAO is a small, autonomous, humanoid robot that is completely programmable and thus much appreciated by academics for its customizability. The users of the robot are diabetic children who have to learn to cope with their disease. At the time of writing, the ALIZ-E project is in its fourth year. As illustrated in Figure 1, the main deliverable of the project is an integrated system comprising different modules (Blanson Henkemans et al., 2013). These modules are: a dialogue model, a user model and reasoning engine, a memory, and sensors for automatic speech and gesture recognition. The architecture includes different child-robot activities, such as playing a quiz, a dance or an imitation game. Because this system is developed incrementally and not all features have fully matured, some of the robot's functionality is simulated in a Wizard of Oz (WoOz) setting in which the researcher partly simulates some functionality of the robot, whereas other behavior of the robot is performed autonomously.

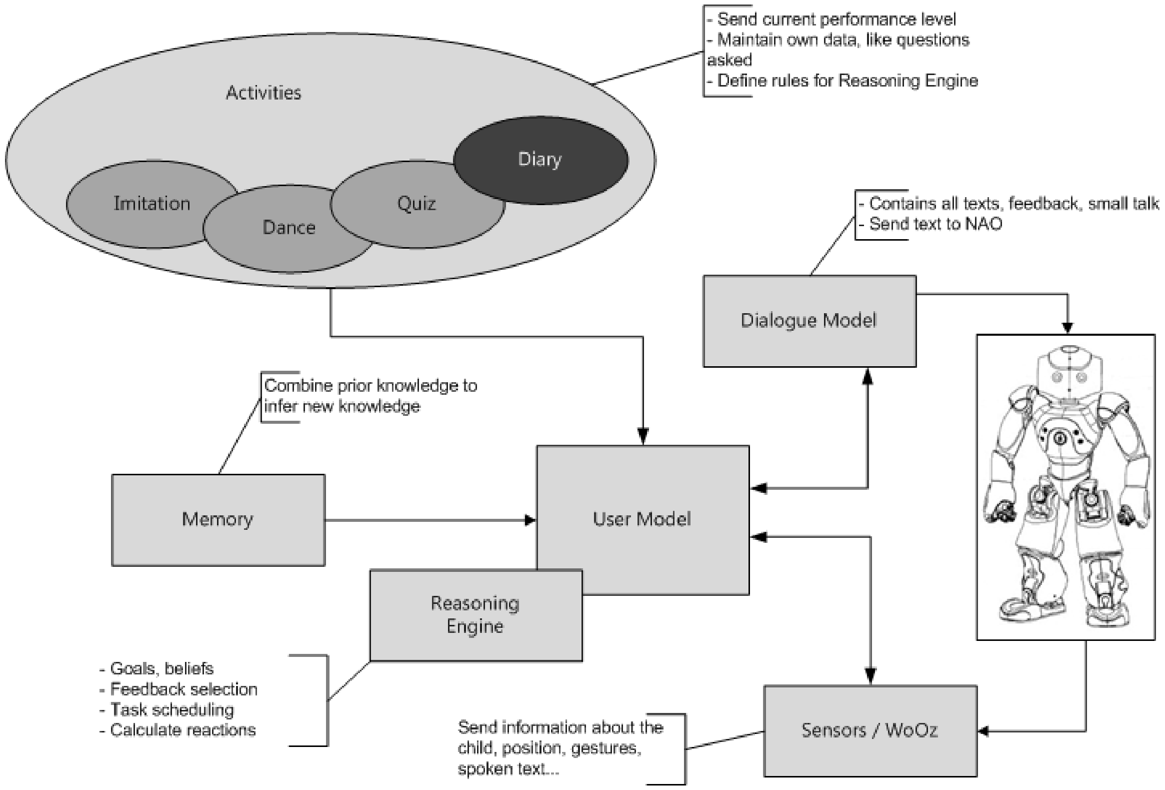

Figure 1 ALIZ-E integrated system from (adapted from Blanson Henkemans et al, 2013)

Previous research by Looije, van der Zalm, Neerincx and Beun (2012) within the ALIZ-E project showed that children who played a quiz game with either a physical robot or a virtual character, preferred the robot over the virtual character. Their attention was kept longer, which in turn has the potential to positively influence their performance on the quiz. We hypothesize that the robot will have the same positive influence on task performance in the activity of keeping a diary. Therefore, we choose to use a robot rather than a virtual character in this study. In this thesis we will answer the following main research question:

How can a robot contribute to the activity of keeping a web-based diary together with diabetic children?

To build a social robot that is capable of supporting and motivating a child in the task of keeping a diary is a complex process. Children with diabetes require a very delicate approach because the way they see themselves and their diabetes now, determines in great part how well they will manage their condition in the future. Social robots - while innovative and exciting - are not very robust, and it may prove difficult to design a robot that acts in a believable and trustworthy manner. We will have to find ways to overcome the technical difficulties and shortcomings of robot technology if we want to make this a successful venture. To this end we perform a literature study on self-management of diabetes, social robots and the human-robot relationship to better understand the context in which this explorative pilot study takes place. We then break down the main research question into several sub questions and define measures we can use to answer these questions. Based on the literature and a few creative ideas of our own, we develop a robot dialogue model that forms the basis of the diary activity. The main role of the experiment is to answer the research question, but the results will also provide us with meaningful insights into potential improvements for the dialogue model and the activity of keeping a diary as a whole.

2 Theoretical Background

In this chapter we will learn more about what it means to have diabetes. We will see how self-management of diabetes is a complex process that involves an important shift in responsibility as the child grows older. We learn how children frequently struggle to cope with their diabetes and why it is so hard to adhere to their treatment regimens. It is important to understand these things if we want to be able to help young diabetes patients. Next, we will outline the main challenges in developing social robots. We briefly discuss the advantages and disadvantages of using a physical robot rather than a virtually simulated one; and investigate why humans sometimes treat robots as human actors. After that, we proceed to explain how adapting the robot's dialogue and behavior using a user model, displaying socially intelligent behavior and sharing information about oneself can help create a lasting social bond between a human and a robot, which is the ultimate goal of the ALIZ-E project. Finally, we summarize the results of this literature study and elaborate on what this means for our experiment.

2.1 Diabetes mellitus

Diabetes mellitus (literally "sweet circulation"), often simply referred to as diabetes, is a group of metabolic diseases where the blood in the human body contains too much glucose (sugar). In healthy people, the carbohydrates from nutrition are broken down into glucose via the digestive system. The pancreas produces a hormone called insulin to process the glucose so that the cells in the different organs can use it as fuel. In people with diabetes this system falters or does not work at all: little or no insulin is created, or the cells have become insensitive to the insulin. As a consequence, the glucose can no longer be used as fuel, which causes the blood glucose levels to rise (Idenburg, Van Schaik, & De Weerdt, 2012). Prolonged high blood glucose (hyperglycemia) can cause serious complications such as retinopathy with potential loss of vision, kidney failure, cardiovascular disease and even coma. But low blood sugar (hypoglycemia) is just as dangerous with possible complications ranging from fainting to seizures and permanent brain damage. For diabetics, monitoring and controlling blood glucose levels are of vital importance.

The vast majority of diabetics fall into two broad categories. In one category, type 1 diabetes, the body mistakenly destroys its own cells in the pancreas that produce insulin. The exact cause of type 1 diabetes is still not entirely clear. Heritance most likely plays a role, as well as environmental factors such as nutrition and infections. Type 1 manifests itself at all ages, but usually during childhood or adolescence. About 98 percent of the children with diabetes suffer from type 1 (Baan & Poos, 2012). Because people with this type of diabetes do not produce enough insulin, they need to be treated with insulin directly. The treatment essentially focuses on glucose control and preventing complications. People with diabetes type 1 will die without insulin.

In the other, much more prevalent category, type 2 diabetes, the cause is a combination of reduced sensitivity to insulin (insulin resistance) and a slowed or reduced insulin production or delivery. This causes a shortage of insulin for the body to process glucose well. About 90 percent of all people diagnosed with diabetes have this type. Risk factors for type 2 are genetic inheritance, obesity, physical inactivity, unhealthy diet, smoking, high blood pressure and high age. Diabetes mellitus type 2 is a progressive disease which means that patients will be increasingly needing blood glucose lowering medication as their diabetes progresses. It is also strongly associated with severe co-morbidity (cardiovascular diseases, blindness and chronic kidney damage). A lot of people with type 2 diabetes die prematurely from cardiovascular problems. The treatment for this type of diabetes focuses on advising lifestyle changes aimed at weight reduction and pharmacotherapy. People with type 2 diabetes can remain undiagnosed for many years.

A recent study by Danaei et al. (2011) revealed that approximately 350 million people suffer from some form of diabetes worldwide. Since 1980, the number of diabetics has almost doubled, and it continues to rise explosively. This will have tremendous consequences for the world's economy and society. Budget cuts and a shortage of health care personnel force patients to be more responsible for their own care.

2.1.1 Self-management of diabetes

Self-management of diabetes is an active and proactive process; it is daily, lifelong, and flexible, and it involves shifting and sharing responsibility for diabetes care tasks and decision-making in frequent collaboration with health care providers. Self-management of diabetes consists of many varied activities related to dosing insulin, monitoring metabolic control and regulating diet and exercise to name just a few (Schilling, Grey, & Knafl, 2002). The American Association of Diabetes Educators has identified seven key self-care behaviors (AADE7) that help diabetics manage their diabetes (American Association of Diabetes Educators, 2013). Each of the seven behaviors was subjected to a systematic literature review by the AADE and adherence to the behaviors was proven to be beneficial to patients. Some of these behaviors are more applicable to type 2 diabetics than type 1 diabetics. For instance healthy eating habits and an active lifestyle can help a patient lose weight, which is an important goal in the management of type 2 diabetes. The AADE7 self-care behaviors are listed in Table 1.

Table 1 AADE7 Self-Care Behaviors (American Association of Diabetes Educators, 2013)

Behavior	**Description**
Healthy eating	Making healthy food choices, understanding portion sizes and learning the best times to eat are central to managing diabetes. Children and teenagers can optimally grow and develop if they make the appropriate food selections. And many adults may be able to delay the need for medication if they can control their weight and achieve optimal blood glucose levels through a healthy diet.
Being active	Regular activity is important for overall fitness, weight management and blood glucose control. Those at risk for type 2 diabetes can reduce that risk with appropriate levels of exercise, and those with diabetes can improve glycemic control. An active lifestyle has also been proven to improve body mass index, enhance weight loss, help control lipids and blood pressure and reduce stress.
Monitoring	People with diabetes need to monitor their blood glucose daily in order to assess the influence of food, physical activity and medication on their blood glucose levels. Monitoring, however, does not stop there. People with diabetes also need to regularly check their blood pressure and weight, as well as check their feet for any problems. Frequent check-ups in the hospital are not uncommon for diabetics.
Taking medication	Depending on what type a person has, people with diabetes need insulin or pills to

	treat their condition. Effective drug therapy in combination with other healthy lifestyle choices can significantly reduce the risk for diabetes complications.
Problem solving	Problem solving skills are especially important for people with diabetes because on any given day, a high or low blood glucose episode will require them to make rapid, informed decisions about food, activity and medications that directly influence their physical well-being.
Reducing risks	Effective risk reduction behaviors such as smoking and drinking cessation, and regular examinations can reduce the risk for complications and maximize health and quality of life. An important part of self-care is learning to understand, and practice these healthy behaviors.
Healthy coping	Diabetes is strongly associated with feelings of psychological distress, which directly affects health and indirectly influences a person's motivation to keep their diabetes in control. When motivation is low, it becomes increasingly difficult to keep up with healthy habits required for effective self-management.

Diabetes educators can assist people in gaining knowledge about the effects of food and exercise on blood glucose, and helping patients address physical, emotional and financial obstacles that may prevent them from adopting new habits. If the above mentioned healthy lifestyle habits are not an already established part of a patient's lifestyle, it may take more than knowledge and good intentions to adopt and maintain them. Especially people with low confidence in their ability to adopt new habits may benefit from the guidance and support offered by diabetes educators such as nurses, dietitians and pharmacists. For diabetes patients diagnosed at a very young age (type 1), having a strong support network is vital for managing their diabetes effectively. Frequent contact with certified professionals has been shown to improve the HbA1c value (glycated hemoglobin) and decrease hospitalization rates (Howells et al., 2002; Svoren, Butler, Levine, Anderson & Laffel, 2003).

2.1.2 Self-management of diabetes in children

The American Diabetes Association (ADA) (2005) stated that children have characteristics and needs that dictate different standards of care. Yet the literature on self-management rarely differentiates between self-management in children and in adults (Schilling, Grey & Knafl, 2002). The management of diabetes in children must take the major differences between children of various ages and adults into account. It is not just their bodies that react differently to insulin doses and hypoglycemic events; type 1 diabetes patients are often diagnosed at a very young age and are unable to manage their own diabetes effectively. Parents and other adults need to be involved so that the child can gradually transition toward independence in diabetes self-management. There are few hard rules on what self-management capabilities children and adolescents should have at various points in their development, but the ADA has formulated some helpful guidelines on priorities and issues in self-management (American Diabetes Association, 2005) that are summarized in Table 2.

Table 2 Appropriate self-management capabilities by age (American Diabetes Association, 2005)

Age	Priorities and issues in self-management
Infants (<1 year)	Infants are unable to communicate sensations associated with hypoglycemia. Moreover, the brain of infants is still developing, so the consequences of severe hypoglycemia may be even greater than in older children. Parents carry full responsibility for their diabetic child. They may also need emotional support from a diabetes team that understands the difficulties and stress associated with dealing with an infant with diabetes.
Toddlers (1-3 years)	Parents still carry most of the burden for the diabetes management of toddlers. Children at this age may struggle with parental discipline and throw temper tantrums where they refuse to eat (risking hypoglycemia). Parents will need the support of a diabetes team to make sure they are not overly cautious in attempting to prevent hypoglycemic events and do not interfere with the child's ability to try out new things.
Preschoolers and early school aged children (3-7 years)	Most children at this age are somewhat capable of testing their own blood glucose and keeping records of measurements. In some cases they can also count carbohydrates themselves. However, they often lack the fine motor control, cognitive development and impulse control necessary to be an active participant in most aspects of their diabetes care. Parents still provide most of the care, together with watchful teachers or school nurses. Parents are often hesitant to share the care for their child because of fear for undetected hypoglycemia.
School-aged children (8-11 years)	School-aged children can begin to assume more of the daily diabetes management tasks, such as insulin injections and blood glucose testing. Pump treatment is often used in this age-group because it makes it easier for children to bolus appropriately for standard carbohydrate meals. It is important to note that the children still need significant assistance and supervision from knowledgeable adults for management decisions. There is still a significant fear in both parents and children for hypoglycemic events. Research has shown that parents often over treat symptoms in order to maintain higher blood glucose levels.
Adolescents	The adolescent typically strives for independence from parents and peer acceptance, which can interfere with the adolescent's judgment capabilities. While physically capable of performing the tasks related to their own diabetes management, adolescents still need some guidance and supervision from parents. The challenge lies in finding the right degree of parental involvement that does not make the adolescent uncomfortable. Diabetes care teams attempt to assist the youth in transitioning to more independent self-management.

When children reach puberty (around the age of 10-12), their lives start to revolve more around school and their social lives rather than their diabetes management. Coupled with the shifting source of care as the children grow older, and the strong natural fluctuations in blood glucose levels associated with puberty, makes for a very difficult time in diabetes self-management. The way children cope with their illness depends on their age as well as their emotional and cognitive development.

2.1.3 Coping with diabetes

The seminal work of Geist (1979), Tarnow & Tomlinson (1978) and Wishner and O'Brien (1978) shows that the diagnosis of insulin-dependent diabetes mellitus (IDDM) imposes considerable stress on young patients and their families. This is further confirmed in later work by Sullivan-Bolyai, Deatrick, Gruppuso, Tamborlane and Grey (2003) and Whittemore, Kanner and Grey (2004). Diabetic children and their families have to adjust their lives, learn a substantial amount of new information and become proficient in the skills necessary for diabetes management. School may pose a challenge for some diabetic children because they feel different from others (American Diabetes Association, 2005). Their illness is often misunderstood ("you probably got diabetes from eating too much sugar"), and participating in school activities and sports requires preparation and careful monitoring. It is important that children with diabetes regularly participate in activities with peers to facilitate the forming of normal peer relationships.

Research has shown that children with diabetes have a two-fold greater prevalence of depression, and adolescents up to three-fold greater (with rates as high as 33%), than youth without diabetes (Grey, Whittemore & Tamborlane, 2002). Depression may lead to poorer metabolic control in diabetes, which in turn could lead to complications and other poorer outcomes. Other than depression, young diabetes patients are often diagnosed with generalized anxiety disorder (Kovacs, Goldston, Obrosky, & Bonar, 1997). This likelihood increases when the children are frequently hospitalized. Incidence rates are highest during the first year of the medical condition. Suicidal thoughts have also been found to be more prevalent in diabetes patients than healthy adolescents, although actual suicide rates are comparable to that of the general population (Goldston, et al., 1997). Among those who did attempt suicide, diabetes-related methods were used (e.g. insulin overdose). Another serious risk is eating disorders, especially in girls with diabetes. They sometimes refuse to take their insulin as a means to control their weight (Affenito & Adams, 2001; Polonsky, Anderson, Lohrer, Aponte, Jacobson & Cole, 1994). In a study of 341 female patients with diabetes between 13-60 years of age, approximately 31% reported intentional insulin omission (Polonsky, Anderson, Lohrer, Aponte, Jacobson, & Cole, 1994). Insulin omitters have poorer glycemic control, more diabetes-related hospitalizations, and higher occurrences of retinopathy and neuropathy. The consequences of this behavior could be severe. Anorexia and bulimia are very dangerous for diabetes patients as the mortality rates are almost five-fold higher for adolescents with both anorexia and diabetes, as compared with anorexia alone, and almost 16-fold higher than for diabetes alone (Nielsen, Emborg, & Molbak, 2002).

Interventions which focus on coping skills training (Boardway, Delamater, Tomakowsky & Gutai, 1993; Grey, Boland, Davidson, Li & Tamborlane, 2000) and peer support (Anderson, Wolf, Burkhart, Cornell, & Bacon, 1989) have been demonstrated to lead to improved quality of life, as well as better metabolic control.

2.1.4 *Motivation to manage diabetes*

To the outside world it is often difficult to comprehend why children with a life-threatening condition such as diabetes do not adhere to their treatment regimens (Lask, 2003). Poor adherence is a common and challenging clinical problem, particularly for chronic illnesses. Coercing the child into better managing his/her diabetes is not an option for two reasons: first, coercion often has the opposite effect and causes the child to rebel even more; and second, because from a practical standpoint it is impossible to uphold this approach. Children go to school and play with their friends, so parents are not always present to monitor their child.

Adherence is influenced by many factors, so unfortunately there is no single method to improve and sustain it. Informing the child of the risks of poor diabetes management rarely solves the problem. The child is usually aware of the health risks, but lacks the motivation to change. Lask (2003) has developed what is called "motivational enhancement therapy" (MET). MET is characterized by a sincere curiosity and eagerness from the health care practitioner to learn more about the child's perspective of the situation. The focus is on trying to *understand* the child's view rather than making active attempts to change the child's attitude and behavior. Enhancing motivation takes time and cannot be forced. The best approach is to help the child focus on the *reasons* for poor adherence by using techniques such as asking open-ended questions rather than "closed" questions, reflective listening and by affirming and summarizing a child's point of view.

2.1.5 *Monitoring*

Self-monitoring of blood glucose (SMBG) plays a critical role in the management of insulin-dependent diabetes mellitus (IDDM). Patients need to test their blood glucose levels at least four times a day and adjust insulin doses for high and low blood glucose levels. In addition to frequent measurements, accurate record keeping of SMBG results (using a diabetes diary) is necessary for the patient and health care practitioner to evaluate diabetes control and make appropriate treatment adjustments on the long term. Unfortunately, there is evidence that adherence to both of these requirements is problematic for many patients (Gonder-Frederick, Julian, Cox, Clarke & Carter, 1988). Patients do not take enough measurements (56.6% only measures their blood glucose two to three times a day), alter values in their diaries to make them more acceptable and omit less desirable readings. Research on monitoring of diabetes is often limited to just the monitoring of blood glucose values; but health diaries can be used for so much more.

For patients suffering from a chronic illness, keeping a health diary is a great way to monitor how they feel on a daily basis. But even if you are relatively healthy, a health diary can help to manage and organize health-related information, keep track of any symptoms or to identify unhealthy habits and allow you to make changes to your lifestyle. Health diaries are available in a paper format, although since the rise of the internet you can now easily record a health diary on a computer or by using an application on a smartphone (e.g. iHealth Log for the iPhone or Health Diary for Android). In the Netherlands the internet penetration is around 94%, and 38% of the population already goes online using their mobile phone (European Commission, 2011). So it comes as no surprise that the health care sector wishes to keep up with the digitization. It is mostly up to the user what he or she wishes to record in a health diary, but frequently recurring topics in a health diary are: weight, blood pressure, cholesterol, food intake, sleep quality, physical activities, physical symptoms and mood (Bowers, 2010).

For diabetics there are special diaries available that allow them to record blood glucose values, carbohydrate intake, the occurrence of hypoglycemias or hyperglycemias and insulin doses (e.g. OnTrack Diabetes, dbees.com and Glucool for Android phones). Keeping a diabetes diary is usually significantly more work than keeping a diary when you are healthy. Blood glucose values have to be measured frequently and carbohydrates need to be counted throughout the day for appropriate glycemic control. This makes filling in a diabetes health diary a cumbersome task, especially for children who have just been diagnosed with diabetes and who have a lot on their minds anyway. Nowadays many diabetic children use an insulin pump to manage their blood glucose levels. Instead of having to manually prick their glucose levels every so often, they can simply check their pump and administer the right dose of insulin. The pumps can even keep track of previous values (usually a few days back). So why keep a diary at all then? Accurately keeping a diabetes diary is very important because the patient needs to adapt his/her meal plans, exercise routines and medication regimens accordingly (Rosenthal, 2008). Patients need to be able to see patterns in the data and find relationships between glucose values and other things such as exercise and mood. A diary should not just be a log of glucose values because monitoring involves more than that. In the case of young diabetes patients, careful monitoring is of even greater importance because their bodies are still developing. Their treatment needs to be more frequently adjusted than for adults with diabetes.

Several researchers have investigated the added value of electronic diaries over traditional paper-based diaries, although not necessarily in the diabetes domain. In a study on self-monitoring of weight loss and dietary intake (Burke et al., 2012) the authors found that participants recorded significantly more entries per week when they were using a PDA diary with personalized feedback rather than a paper diary (3.2 and 2.2 entries per week respectively). In another study by Palermo, Valenzuela and Stork (2004) the researchers found that children who kept a digital pain diary completed significantly more entries than children in the paper diary condition (6.6 versus 3.8 entries respectively). Not only were the compliance rates of e-diaries much higher, the diaries entries were also found to be more accurate. On the long term, patients using electronic diaries preferred them to paper diaries and showed much higher rates of compliance and satisfaction (Jamison et al., 2001). Using an electronic diary thus seems to be an effective and practical way to monitor a child’s health and well-being, but there are still challenges to be overcome. One of the main problems is that most of the currently available digital diaries are aimed at the adult audience. They are plain, factual and hardly interesting for children. The challenge lies in creating or modifying a diary in some way so that it remains interesting over a longer period of time.

2.1.6 Summary

In Table 3 we summarize the lessons learned from the literature on diabetes and determine the implications for our study.

Table 3 Implications of diabetes theories for personal robot support of school-aged children keeping a diabetes diary

Diabetes theories	Lessons learned	Implications for experiment
Self-management of diabetes	Self-management of diabetes is a complex, active and lifelong process. A strong social support network is necessary to effectively	The child should be able to share emotional experiences with the robot.

	manage diabetes.	
Self-management of diabetes in children	Parents take on most of the responsibilities when the children are young, but as they grow older they need to start taking on more responsibilities. This is a difficult time for children.	The activity of keeping a diary is not something the child will be looking forward to.
Coping with diabetes	Children with diabetes are a fragile group. Interventions which focus on coping skills training and peer support lead to improved quality of life and better metabolic control.	The robot needs to be an understanding peer rather than a coercive educator.
Motivation to manage diabetes	Motivating children takes time and cannot be forced. Motivational enhancement therapy (MET) focuses on trying to understand the child's view rather than making active attempts to change the child's attitude and behavior.	Ask open-ended rather than closed question, use reflective listening techniques, and affirm and summarize a child's point of view.
Monitoring	Children typically do not keep a diary. Digital diaries instead of paper diaries yield higher adherence results.	Use a digital diary that is suitable for use by children.

2.2 Social robotics

Robotics is a branch of technology that deals with the design, construction, operation, and application of robots (Oxford dictionary, 2013). Robots are often used to replace humans in the assistance of performing repetitive and dangerous tasks, for example in the automotive or construction industry. Although most robots that are used possess virtually no human-like characteristics, the robots we see on the news and in the movies today often do take a humanoid form. They are increasingly designed to be our pets, assistants, teachers and even emotional companions (Lee, Peng, Jin & Yan, 2006). These robots act as partners rather than tools. Some examples are shown in Figure 2.

Figure 2 From left to right: AIBO, a robot dog designed by Sony; Paro, a therapeutic robot designed as a companion mostly for elderly people; ASIMO, an advanced humanoid robot designed by Honda.

When a robot autonomously interacts and communicates with humans or other autonomous physical agents by following social behaviors and rules, we call it a social robot (Agarwal, Shahin, & Michael, 2013). Social robots are much more complex than non-social robots because they have to possess some internal understanding of the social model of human society and adapt their interaction much like a human interaction partner would (Ge, 2007); whereas a non-social (functional) robot can simply focus on performing the specific task it was built for. Unfortunately, currently available 'social robots' are still largely inadequate in terms of interactivity, intelligence, mobility and social skills. Robots are generally expensive, easily damaged, and can only perform a very specific task under very specific circumstances. According to Ros et al. (2011), the three main challenges in social robotics yet to be overcome are:

1. *Contingent responding in dynamic social environments*: an action performed by a robot will almost always prompt some reaction from its user(s). Adequately predicting and handling of these reactions (and subsequent reactions) is one of the main challenges.
2. *Interpretation of social sensory information*: the interpretation of single modalities such as gesture or language is still quite challenging, but social robots often encounter even more complex situations where they have to make sense of several modalities (with potentially conflicting information) at the same time.
3. *Designing sociable robots*: creating believable, contingent behavior of social robots remains a challenge. This problem largely stems from the previously mentioned challenges of endowing robots with the capacity to correctly interpret the social world, thus making it difficult to construct appropriate responses.

Unlike functional robots which often have to perform labor-intensive work, social robots do not necessarily need physical embodiment to accomplish their goals. These tasks can often be performed just as well by a virtual 3D representation of the same robot, which costs considerably less and is much more robust. But a physical form does offer substantial benefits compared to virtual robots.

2.2.1 The effect of embodiment

In a study conducted by Wainer, Feil-Seifer, Shell and Mataric (2007) participants were asked to rate a robot's social abilities in a structured task based on the Towers of Hanoi puzzle, differentiating between a physical robot and a simulated one (a computer simulation of the same robot shown on a screen). The participants felt that an embodied robot (a robot with a physical presence) was more appealing and perceptive of the world around it than a non-embodied robot. Their impression of the robot's watchfulness, helpfulness, and enjoyability was significantly affected by embodiment. Similar results were found by Fasola and Mataric (2011) in a study comparing physical and virtual embodiment in a socially assistive robot exercise coach for the elderly. The users strongly preferred the physical embodiment over the virtually simulated robot. The interaction with the physical robot was rated as more enjoyable and useful. In another study conducted by Leyzberg, Spaulding, Toneva and Scassellati (2012) participants were asked to solve a set of puzzles while receiving the occasional game play advice from a robot tutor. It was concluded that a physical embodiment can produce measurable learning gains in cognitively-demanding tasks. Physical embodiment has also been found to evoke a higher degree of user engagement and presence (Deshmukh et al., 2012).

When a person interacts with a robot as if it were an actual social actor, we say that the robot's *social presence* is high. Lee (2004) defines social presence as "a psychological state in which virtual (para-authentic or artificial) actors are experienced as actual social actors in either sensory or non-sensory ways". Jung and Lee (2004) found that people's imagination of robots as actual social actors is positively influenced by physical embodiment. Social presence does not always have to correspond with physical presence. Research suggests that a remote physical robot on a screen (not to be confused with a *virtual 3D representation* of the robot, which does not have a physical form in the real world) has almost the exact amount of social presence as a robot that is located physically near the user (Powers, Kiesler, Fussell & Torrey, 2007). In a health interview with a virtual agent, a remote projected robot or a physically present robot, the last two were found equally engaging, elicited equal disclosure, but the projected robot was considered to have somewhat less influence.

Because people tend to respond to technology socially, trust is a key factor for the acceptance of technology and the establishment of interpersonal relationships (Lee & See, 2004). The user needs to trust that the robot will act in a consistent manner and that its motives are pure. People are generally more willing to trust a robot rather than a virtual agent (Naito & Takeuchi, 2009). In a study by Kiesler, Powers, Fussell and Torrey (2008), the trustworthiness and respectfulness of the robot was rated more positively by participants than that of the virtual agent. Komatsu and Abe (2008) found similar results in an experiment where they compared the effects of an on-screen agent and a robotic agent on user's behavior in a non-face-to-face interaction.

2.2.2 Animism and anthropomorphism

Piaget (1929) coined the term *animism* to describe children's beliefs that inanimate objects are alive and have their own free will. A similar phenomenon is called *anthropomorphism*. The American Heritage Dictionary (2009) defines anthropomorphism as "the attribution of human motivation, characteristics, or behavior to inanimate objects, animals, or natural phenomena". The terms anthropomorphism and animism are often used interchangeably in literature. The difference lies in the attribution of a spiritual soul or life in animism; whereas someone who anthropomorphizes an object does not necessarily believe it to be alive.

There is compelling evidence that suggests that children display anthropomorphism and animism towards robots (Michotte, 1963; Tremoulet & Feldman, 2000; Bumby & Dautenhahn, 1999; Pitsch & Koch (2010). Especially humanoid robots are readily ascribed human characteristics such as being able to feel emotion and having their own goals and motivations. Children *want* to believe that the robot is capable of such feelings. This presents a challenge to robot designers to match these expectations and build a robot that children are happy to engage with. When a robot does not behave as the child would expect, the reaction is often negative. For example in the study by Weiss, Wurhofer and Tscheligi (2009), it was found that when a robotic pet dog (AIBO) did not fulfill their expectations (e.g. when the dog did not come when it was called), the children were disappointed. Yet despite the letdown, the children continued to interact with the robot. This suggests it may not be necessary to build a robot that displays perfectly predictable behavior. A consistency that is high but not perfect makes for the most interesting interactions between a child and a robot (Beran, Ramirez-Serrano, Kuzyk, Fior & Nugent, 2011).

2.2.3 Summary

We summarize the lessons learned from this sub chapter on social robotics and the implications for our study in Table 4.

Table 4 Implications of social robotics theories for personal robot support of school-aged children keeping a diabetes diary

Social robotics theories	Lessons learned	Implications for experiment
Embodied vs. virtual	An embodied robot actor triggers greater enjoyment, support and stimulation than a virtual robot and thus is more capable of contributing to an improvement in task performance (adherence).	Use a physical rather than a virtual robot, which is either physically present in the same room as the child or shown remotely on a screen.
Animism and anthropomorphism	Children like to attribute human feelings and characteristics to robots and can be disappointed when the robot acts in a manner that is inconsistent with their cognitions.	Facilitate the attribution of human characteristics by creating a background story for the robot. The robot has to act in a highly consistent manner but does not have to be perfect to be interesting to children.

2.3 Building social bonds

A social robot likely interacts with its human user on a daily basis. The user may be impressed by the robot's capabilities at first, but when he or she sees the robot performing the same tricks the next day, the interaction quickly becomes dull (Oh & Kim, 2010). The novelty of interacting with a social robot typically wears off after one or two encounters. It is challenging to develop a robot that remains interesting over a longer period of time. To leave a lasting impression, the robot needs to be able to adapt to its user, display characteristics of social intelligence toward its user and be able to form a long-lasting bond with its user through mutual self-disclosure. Each of these aspects will be elaborated on in the following sub sections.

2.3.1 *Adaptive dialogue and behavior*

Robots not only have to carry out their tasks, they also have to be able to appropriately respond to input from their users. Human designers cannot predict all possible circumstances and challenges a robot will encounter during its lifetime, so the ability for robots to adapt and learn in their environment is fundamental (Breazeal, 2004). There are several ways in which a robot can adapt its dialogue and behavior to the user, for example by adapting to the user's current information needs or to his/her mood. The way the robot adapts to the user, depends on its user model.

User modeling is a term used in human-computer interaction that describes the process of building up and modifying a user model. The user model is an internal representation of the user that serves as a basis for any adaptive changes to the system's behavior (Fischer, 2001). A user model typically includes any of the following: the user's name, age, interests, skills, knowledge, goals, plans, preferences, dislikes, or any other data about the user's behavior and interactions with the system. This information can be gathered in several ways: by explicitly asking the user while (first) interacting with the system, through learning from observing and interpreting interactions with the system, or by asking for feedback and altering the user model by adaptive learning (Johnson & Taatgen, 2005; Hothi & Hall, 1998). The adaptability of a robot depends on the type of model that is used. For example: a static user model only gathers the main data and shifts in the user's preferences are not registered; whereas a dynamic model allows for the recording of changes in the user's interests, learning progress or interaction with the system. The latter makes for a much more realistic experience, but also costs a lot more time and effort to build and maintain. A user model allows the robot to adapt its dialogue to a range of users: novices and experts, children and adults, etc. (Fong, Thorpe & Baur, 2003). It also allows the robot to modify its behavior to match a user's capabilities.

An example in which a robot relies on a user model is in a situation where information is being conveyed to and elicited from a user. The robot must be capable of engaging the person in the interaction. An adaptive robot estimates the information needs of the individual user and changes its dialogue to suit these needs. For instance, when a user collaborates with the robot on a task for the first time, his/her information needs will be high. But he/she will have far less need for explanations and tips in subsequent collaborations. Generally, most social robots respond in scripted ways that do not account for individual differences between users (Torrey, Powers, Marge, Fussell & Kiesler, 2006) and a user model (if present at all) is often static rather than dynamic.

2.3.2 *Social intelligence*

Human-robot interaction poses many challenges regarding the difference in 'social behavior' between robots and humans. To humans, most social 'rules' come naturally. For example: turn-taking in a conversation or showing empathy for someone is considered to be indicative of social behavior. Sometimes referred to as "people skills", social intelligence describes a person's ability to understand and manage relationships with others. A more broad scientific definition is by Vernon (1933). He defines social intelligence as "a person's ability to get along with people in general, social technique or ease in society, knowledge of social matters, susceptibility to stimuli from other members of a group, as well as insight into the temporary moods of underlying personality of strangers".

There are many ways to endow a robot with social skills and capabilities. In order to decide which social skills are required, one has to take into account the context in which the interaction takes place, the application domain and the nature and frequency of contact with humans need to be analyzed, according to a set of evaluation criteria (Dautenhahn, 2003) shown in Table 5.

Table 5 Evaluation criteria to identify social skill requirements (Dautenhahn, 2003)

Criteria	**Range**	
Contact with humans	None or remote contact	Repeated long-term physical contact
Robot functionalities	Limited or clearly defined functionality	Functionality that is open, adaptive, and is shaped by learning
Role of robot	Machine or tool	Assistant, companion or partner
Requirements of social skills	Not required or not desirable	Essential

The need for social intelligence increases when there is frequent contact with humans, the robot is highly adaptive and acts as an assistant, companion or partner. In Table 5 this is the right hand side of the range. When the context in which the robot operates is more on the left hand side of the range, the need to endow the robot with social skills decreases.

De Ruyter, Saini, Markopoulos and van Breemen (2005) defined a list of aspects indicative of social intelligence for the iCat in a home dialogue system, which is shown in Table 6. They found that these aspects made the robot distinguishably more socially intelligent than a neutral one.

Table 6 Aspects indicative of social intelligence (De Ruyter et al., 2005)

Behavior aspect	**Description**
- Attentive listening	By looking at the participant when he/she talks and occasionally nodding its head.
- Using non-verbal cues	Responding to repeated wrong actions on the part of the participant by offering help.
- Assessing relevance of information about a problem	By stating what is going wrong before offering the correct procedure.
- Being nice and pleasant to interact with	By staying polite, mimicking facial expressions (smiling when participant smiles, for example), being helpful.
- Paying attention to affective signals	By responding verbally or by displaying appropriate facial expression to obvious frustration, confusion, or contentment.
- Displaying interest in the immediate environment	The immediate environment being the participant and the equipment used in tasks, by carefully monitoring the person and the progress of the tasks.
- Knowing rules of etiquette	By not interrupting the participant when he/she is talking.
- Remembering personal details	Addressing the participant by name, remembering login information, and passwords if asked.
- Admitting mistakes	By apologizing when something has gone wrong, but also when no help can be provided upon participant’s request.

- Being expressive	By showing facial expressions while talking, if appropriate.
- Thinking before speaking and doing	By showing signs of thinking (with facial expression) before answering questions or fulfilling the participant's request.

The participants in the study by De Ruyter et al. were more 'social' with the socially intelligent iCat. They were much more inclined to laugh and to divert conversation to a relational level, asking the robot questions about what type of music it listened to or asking for its opinion. The socially intelligent behavior made the robot friendlier and easier to approach.

2.3.3 Self-disclosure

Studies have shown that self-disclosure plays a central role in the development and maintenance of relationships as well as psychological well-being (Collins & Miller, 1994; Altman & Taylor, 1973; Jourard, 1964; Laurenceau, Feldman Barrett, & Pietromonaco, 1998). Self-disclosure is defined as (Borchers, 1999) "sharing information with others that they would not normally know or discover. Self-disclosure involves risk and vulnerability on the part of the person sharing the information." A useful way of understanding self-disclosure is through the Johari window. This technique in cognitive psychology was created by Luft and Ingham (1950), and can be used to help people better understand what they know about themselves and what others know about them. This technique is often used in self-help groups and corporate settings as a heuristic exercise.

The Johari Window has four areas or 'panes': open, blind, hidden and unknown (see Figure 3). The open area (1) contains all information that is known by yourself and known by others. There may also be information that you do not know about yourself, but others do know about you. We call that the blind area (2). Similarly, the hidden area (3) contains information that you know about yourself, but others do not. Dreams, secrets or ambitions are often in the hidden area. And finally the unknown area (4) holds information that neither you nor your peers know about you. Perhaps you have some hidden talent that you have yet to discover.

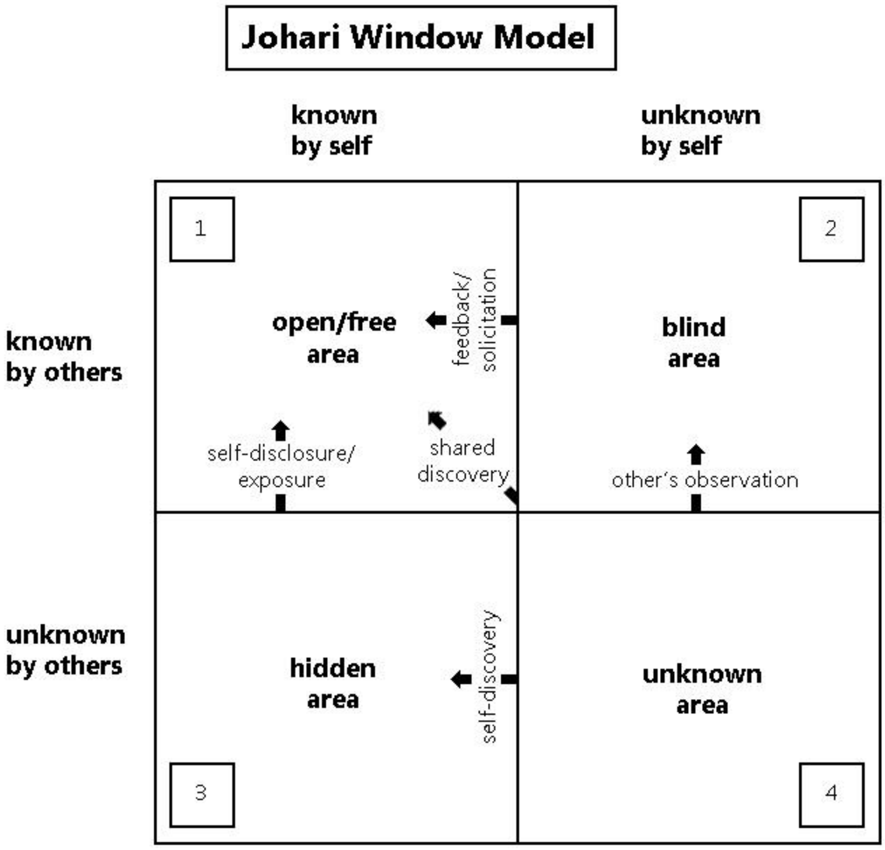

Figure 3 The Johari Window model adapted from Luft and Ingham (1950).

In this model, self-disclosure is the process of telling others about yourself, and therefore moving information from the previously hidden area into the open area, which is now known by both parties. Once one person engages in self-closure, it is implicitly expected that the other person will also disclose information. This is called the *norm of reciprocity*. Reciprocity in social psychology has been described as "a general basic tendency to help those who have helped him/her in the past, and retaliate against those who have been detrimental to his/her interests" (Perugini, Gallucci, Presaghi, & Ercolani, 2003). But the norm can also be found in human dialog. When someone asks you how you are doing, do you not ask him/her the same?

A study by Collins and Miller (1994) found that people who engage in intimate disclosures tend to be liked more than people who disclose at lower levels. People disclose more to others that they like, as well as like others as a result of having disclosed to them. Siino, Chung and Hinds (2008) found that in collaborative tasks with robots, people liked robots better when they disclosed affective rather than task-related information. Another interesting finding was that when people had the ability to control disclosure (on demand vs. automatic disclosure), their sense of control increased, but their liking of the robot decreased. This suggests that there is always a potential tradeoff between the perception of control versus likeability in designing collaborative social robots.

2.3.4 Summary

In Table 7 we summarize the lessons learned in this sub chapter on building social bonds between humans and robots. We also list the implications these lessons have for our study.

Table 7 Implications of human-robot interaction theories for personal robot support of school-aged children keeping a diabetes diary

Social robotics theories	Lessons learned	Implications for experiment
Adaptive dialogue	Applying a user model allows for the recording of changes in the child's interests, learning progress or interaction with the system, which elicits a more realistic experience for the child, which in turn contributes to the child's engagement.	The robot gets to know the child over time and adapts the interaction (e.g., verbal and non-verbal communication, the interaction content) to the child.
Social intelligence	Socially intelligent behavior makes a robot friendlier and easier to approach. The social skill requirements of a robot depends on the context in which the interaction takes place. Relatively simple human-human interaction rules can be implemented to simulate social intelligence in robots.	There will be frequent contact with humans, the robot has clearly defined functionalities and performs the role of an assistant or companion. Social intelligence skills are essential for performing this role. We should integrate simple behaviors such as turn-taking and attentive listening to imply social intelligence.
Self-disclosure	Sharing information about oneself with others is instrumental to the development and maintenance of relationships and psychological well-being. People who engage in intimate disclosures are liked more than people who do not. Also, people prefer robots to disclose affective rather than task-related information.	The robot should share information about itself and allow the child to do the same in order to develop a bond. This information should be mainly affective rather than task-related.

2.4 Relevance to the experiment

It is still unclear how diabetes type 1 is triggered, but it is important to understand that it is not something the child is at fault for. Unlike diabetes type 2, there is nothing the child could have done to prevent it. Children with diabetes are often diagnosed at an early age and are too young to take full responsibility for their own care. Parents usually take full responsibility the first few years, but as the child grows older and goes to school, he or she needs to start taking on more responsibilities. In this chapter we have learned that diabetic children are a fragile group at risk for developing all kinds of disorders due to the stress associated with the condition. Peer support and frequent contact with diabetes professionals have been demonstrated to lead to an improved quality of life, as well as better metabolic control. We also learned that if we want to change something about the child's adherence to their treatment regimen, it is important that the focus of any intervention is on trying to understand the child rather than making active attempts to change his/her behavior. The robot could fulfill this role by becoming an understanding peer or friend that the children can confide in if and when they want to. Contact with the robot should be frequent if we wish for it to have a lasting effect on the child's behavior. We have seen from the focus group and the literature on monitoring of diabetes that children typically do not (accurately) keep a diary. A digital diary was demonstrated to yield much better results in terms of adherence. We propose to have the robot help the child keep a digital diary instead of a paper diary to achieve optimal results.

Social robots are becoming ever more prevalent as our pets, assistants, teachers and companions. As exciting as this development sounds, there are still significant challenges to be overcome in the design of social robots. They have to be able to correctly interpret and adequately respond to large quantities of sensory data. Other disadvantages are that robots are generally expensive, easily damaged and built for very specific tasks. But we have also seen from several experiments with simulated robots and physical robots, that having a physical presence has significant benefits. Physically embodied robots were found to be more appealing, perceptive, watchful, helpful, trustworthy, respectful, enjoyable, useful and engaging. Physical robots (or remote physical robots) also have a stronger social presence than virtual robots, which means that people more readily experience the robots as actual social actors. This is also evident in the attribution of human characteristics to robots in a phenomenon known as anthropomorphism. We've seen that robots do not have to live up to each and every expectation of the child. As long as the robot responds consistently, children will continue to interact with the robot. In concrete terms, this means that our robot needs to have a physical body that is either present in the same room, or shown remotely via video to have the largest and most positive impact on the child. It also important that the robot behaves in roughly the same manner during every interaction. This way the child knows what it can expect and it will not be as surprised or disappointed if the robot deviates from his/her expectations.

While building a social robot in itself is challenging, creating a social bond between the robot and the child is even more difficult. The "novelty effect" is often found in human-robot interaction, where the child loses interest in the robot after the first one or two encounters. In the sub section on building social bonds, we learned that by adapting the dialogue and behavior to the user (in this case the child) by utilizing a user model keeps the interaction interesting. There are different ways of building a user model and different types of models that can be used. The interactions with the children will be relatively short and will probably not provide the robot with enough information to dynamically adapt its behavior through learning from observing and interpreting. It is much more realistic given the time span to explicitly ask the user for certain information. By applying a few rules of human-human interaction to robots, we can develop a robot with relatively little effort that displays believable social behavior and is pleasant to interact with. Looking at the evaluation criteria to identify social skill requirements, our project would be somewhere on the middle of the spectrum. The contact with humans is remote and repeated, the robot has clearly defined functionalities for the most part, but it should also be able to handle open-ended questions from the children. The robot performs the role of an assistant or companion, and social skills are essential to performing this role. We saw that there are a few aspects of social intelligence that can easily be integrated in our study; for example remembering personal details (stored in the user model) and by expressing emotions and personal stories. We learned that by sharing information about oneself in turn evokes a response in the other person to do the same. So if the robot were to tell a personal story, we would expect the child to replicate this behavior. Self-disclosure has been shown to influence how much the conversation partner is liked, and how much we like our conversation partner in turn determines how much we disclose to them. If we want the child to tell us how he/she is feeling, it would make sense to have the robot do the same.

3 Research questions

In the introduction we defined the following main research question:

How can a robot contribute to the activity of keeping a web-based diary together with diabetic children?

Now that we have a better understanding of our target audience, the technology we will be working with and the social dynamics in human-robot interaction, we can separate this question into several sub questions. We will briefly elaborate on these questions and what information we will need to answer them. This in turn provides us with the necessary information on how we should set up our experiment.

In the case of keeping a diary, task performance is measured in terms of adherence. Adherence is defined as the extent to which the children keep an accurate account of their values, mood and activities in their diaries on time (meaning on the same day the values were measured). Having frequent contact with a health care professional or peer has been shown to improve diabetes outcomes. We would like to know if the robot can successfully fulfill this role and have a positive effect on diary adherence. The first question we ask ourselves is:

R1: *How does communicating with the robot while filling in the diary help improve children's diary adherence?*

If we want to answer this question, we will need to have two conditions in the study: keeping a diary with the robot, and keeping a diary without the robot. There will need to be multiple interaction moments for both conditions if we wish to see an improvement in diary adherence over time. We also need to know what the situation was like before the intervention; how often do the children keep a diary now? A good indicator for high diary adherence is to compare the number of completed diary entries between conditions. Another would be to see how often the children supplement their diaries with extra information (at a later time or on another day) without being asked to directly. This means we will have to keep log of the diary data, and ask the children about their current diary adherence at the start of the study.

Previous work by Looije, van der Zalm, Neerincx and Beun (2012) showed that one of determinants of task performance (attention, a measure of engagement) was positively influenced by using a robot rather than a virtual character. Other research also showed that interacting with a physical robot has all sorts of advantages, among which a higher degree of engagement. An engaged user typically spends more time on an activity and is more inclined to keep doing whatever it is that he/she is doing. Engagement is thus a mediating factor that can greatly influence a child's diary adherence. We want to know to what extent the children are engaged in our experiment, and therefore ask the following question:

R2: *How engaged are the children with their diaries when they interact with a robot?*

When a child shows active participation during the activity by taking initiative to interact and by maintaining a high attention span throughout the duration of the activity, we can say they are engaged. We could measure how often the child asks or tells the robot something from his/her own initiative. To see if a child is paying attention, we need to be able to see the child, not just the diary. We also need to know how much time the children spend on their diaries. To this end, we will need to record the interaction sessions with the robot, carefully observe the children and log the total time of their interactions with the robot and the diary to answer this research question.

When there are multiple interaction moments for the child and the robot, we will likely see the forming of some sort of relationship. This potential bond is another mediating factor which can positively influence a child's diary adherence. We hypothesize that a child who sees the robot as a friend will be more inclined to continue keeping the diary because of this friendship. We are curious to see how the children treat the robot, so the third question we ask is:

R3: *How does the relationship between the child and the robot evolve over time?*

In order to find out more about the relationship between the child and the robot, we need to ask the child about his/her experiences after each session. They should also be asked to answer questions about their personal feelings towards the robot at the end of the study to determine how they see the robot. A strong sign that the children are bonding with the robot is when they share personal information with the robot, and when they ask it personal questions as they would ask a friend. We need to be able to record this sharing of information in the diary and/or the recording of the sessions to answer this question.

4 Methodology

4.1 Overview

To answer the main research question we performed an experiment in which we had six children keep a diary for two weeks. Every other day the children filled in the diary with help from a personal robot which they were able to contact using a laptop equipped with a webcam and screen-sharing software. The other days they kept the diary by themselves without any such support. The experiment provides us with insight into how the robot contributes to the task of keeping a diary, specifically on the factors adherence, engagement and bonding. The choice for a within-subjects design was a practical one: there was a limited time window between the children coming home from school and the TNO facility closing. We were able to have three interaction sessions with the robot at most, so we were unable to split the group to do a between-subjects design or a stepped wedge design, which would both require more than three sessions on the same day. In sub section 4.2 we describe our participant sample. We needed to find or create a diary that was suitable to test our hypotheses. Children should be able to keep track of their values, emotions and activities so that they can learn how these things influence each other. The robot needs to be someone that the children can trust and relate to so that they are more readily inclined to share personal information with it. It should support the child in keeping the diary, and be able to have a friendly conversation with the child to bond with him/her. We describe the intervention (diary, robot and dialogue) we designed in sub section 4.3. Questionnaires, logs and video recordings are the research instruments we need to gather data about the effectiveness of our intervention. In the questionnaires we can find out more about the children's background, their opinions of the interaction sessions with the robot, and how much they have bonded with the robot after the experiment. Logs are used to gather data on how often and how well the children keep a diary as a measure of adherence. The recordings and observations of the sessions with the robot provide us with insight into the level of engagement of the children. In sub section 4.4 we provide a full overview of the research instruments we used, followed by a list of the materials that were necessary for this experiment in 4.5. As the ALIZ-E project is incrementally developing the robot system, the robot is not yet capable of performing all actions autonomously. We ran a Wizard of Oz experiment in which the robot was partly controlled by the experimenter. We split the group of participants into two groups that interacted with the robot on alternating days. The participant planning and experimental design are described in sub section 4.6. We also decided that the interaction with the robot should be done remotely, as it was physically impossible to visit all children on the same day for two weeks in a row. In sub section 4.7 we show how we designed our setup so that the children could interact with the robot from their own home. We still needed to narrow down exactly how we were going to measure adherence, engagement and bonding in this experiment. We do this in section 4.8, where we list the measures. The exact procedures we followed during the sessions are described in 4.9. Finally, we present a summary of the methodology in 4.11.

4.2 Participants

The target audience for the ALIZ-E project is diabetic children between the ages of 8 to 12. We approached several Dutch hospitals and eventually came to an agreement with the relatively small hospital Ziekenhuis Rivierenland in Tiel. The children needed to be the right age and have a wired or wireless internet connection at home. We did not impose any further selection criteria. Of the 18 eligible patients, six agreed to participate in the experiment. As listed in Table 8, four of the participants were male and two were female. They were between 9 and 12 years old, with an average age of 10.8 (SD = 1.3). Most of the children were diagnosed in early childhood, but there was one child with a more recent diagnosis (in 2011). On average, they had diabetes for six years. Two of the children have or had a grandfather with diabetes, the other children made no mention of diabetic relatives. None of the children had any prior experience with keeping a digital diary.

In exchange for participating in the experiment, the children each received a gift card (€10) for a toy store, as well as a certificate with a picture of themselves and the robot.

Table 8 Participants' demographic and medical data

Gender	Male	4
	Female	2
Age	Youngest	9
	Oldest	12
	Mean	10.8
	Std. Deviation	1.3
Years diabetes	Longest	8
	Shortest	1
	Mean	6
	Std. Deviation	2.4
Family with diabetes	Yes	2
	No	4

4.3 Intervention

In this study we proposed the idea of using a robot to support the children in keeping an online digital diary. In this sub section we will describe exactly what this intervention entails. First, we will discuss the diary we chose to use and the changes that were made to its design. Next, we present the robot and the dialogue model we developed for it.

4.3.1 Diary

If we want children to see the added value of keeping a diary, it needs to be about more than keeping track of blood glucose levels. We need to make them aware of the relationship between blood glucose values and other things such as exercise, mood and activities. Effectively coping with diabetes has been shown to be a real problem for children and adolescents, so we felt that it was really important to record their emotional well-being in terms of mood, appetite and energy. We found and tested several online diaries but found that none of them matched exactly with our wishes. The only one that came close was the diary Mijn Zorgpagina.

The diary is part of the website www.mijnzorgpagina.nl. Mijn Zorgpagina (literally 'my care page') is a website not just for diabetes patients, but also for people with chronic kidney problems or cardiovascular diseases. The website is an initiative of Diabetesvereniging Nederland (DVN), the Dutch Association for Diabetes. The website provides reliable and understandable information for any patients with the above mentioned conditions. Users (both members and non-members of DVN) can make a free personal page and choose what information they wish to display. They can choose from a variety of widgets that are offered. The diabetes diary is one of the widgets that the user can add to his/her personal page (displayed in Figure 4). Other widgets offer for example the latest news, a list of organized activities, a diabetes knowledge guide and a comparison of medical tools and devices.

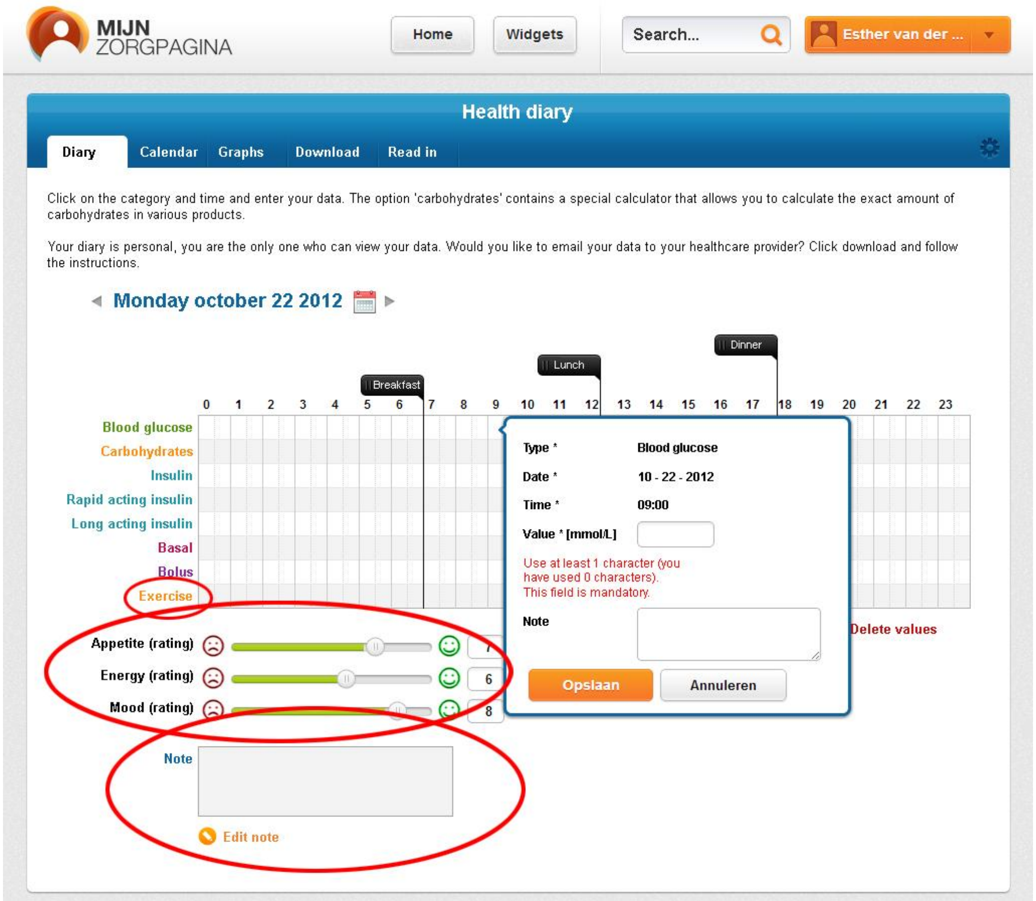

Figure 4 Mijn Zorgpagina diabetes diary screenshot (translated).

We contacted Mijn Zorgpagina about making a few adjustments to the diary so that the diary would become more appealing to children. Thankfully, DVN was enthusiastic about cooperating together as they had been interested in broadening their audience for some time. The current diary only allowed a child to keep track of blood glucose, carbohydrate intake, and insulin levels (with or without pump). We wanted to add the option to keep track of exercise because physical activity greatly influences blood glucose levels. Another change we were looking for was to enable the child to keep track of his/her emotional well-being as well as keeping a log of his/her self-reported daily activities. This should be reflected in the functionality of the diary. Mijn Zorgpagina added an extra 'line' for exercise, three sliders to keep track of the child's ratings for his/her appetite, energy and mood, and a 'note' section to record daily activities. The diary and the changes we made (marked with red circles) are shown in Figure 4.

The diary works as follows. The child logs in and clicks the diary widget to activate it. He/she then drags the black flags to the appropriate times to indicate meal times (breakfast, lunch, dinner). Values can be added either by clicking the corresponding field or by clicking the green *Add value* hyperlink. The sliders at the bottom can be dragged to the left and right to rate the child's appetite, energy and mood. A note can be added by clicking the orange hyperlink *Edit note*. The child can navigate between days by clicking the arrows next to the date at the very top of the diary or by clicking the calendar icon.

4.3.2 The robot

Within the ALIZ-E project the same robot is used throughout all the studies; this robot is the NAO (pronounced as the English word "Now"). NAO is a programmable 57-cm (22.4") tall humanoid robot developed by Aldebaran Robotics. Its body has 25 degrees of freedom (DOF) and is equipped with various communication devices, including a voice synthesizer, LED lights and 2 speakers. Using the two cameras it can track, learn and recognize images and faces. NAO is the most widely used humanoid robot for academic purposes worldwide (Aldebaran Robotics, 2013). More than 550 universities and research labs around the world use the robot. Its versatility makes it an attractive platform for research in areas such as computer science, human-machine interaction, and the social sciences. A picture of the robot we used is shown in Figure 5.

NAO is well-suited for interaction with children largely due to its friendly childlike appearance. Although its face lacks the capability to display emotions (other than changing the position of its head and switching eye color), the robot is capable of showing a wide array of emotions through its body language.

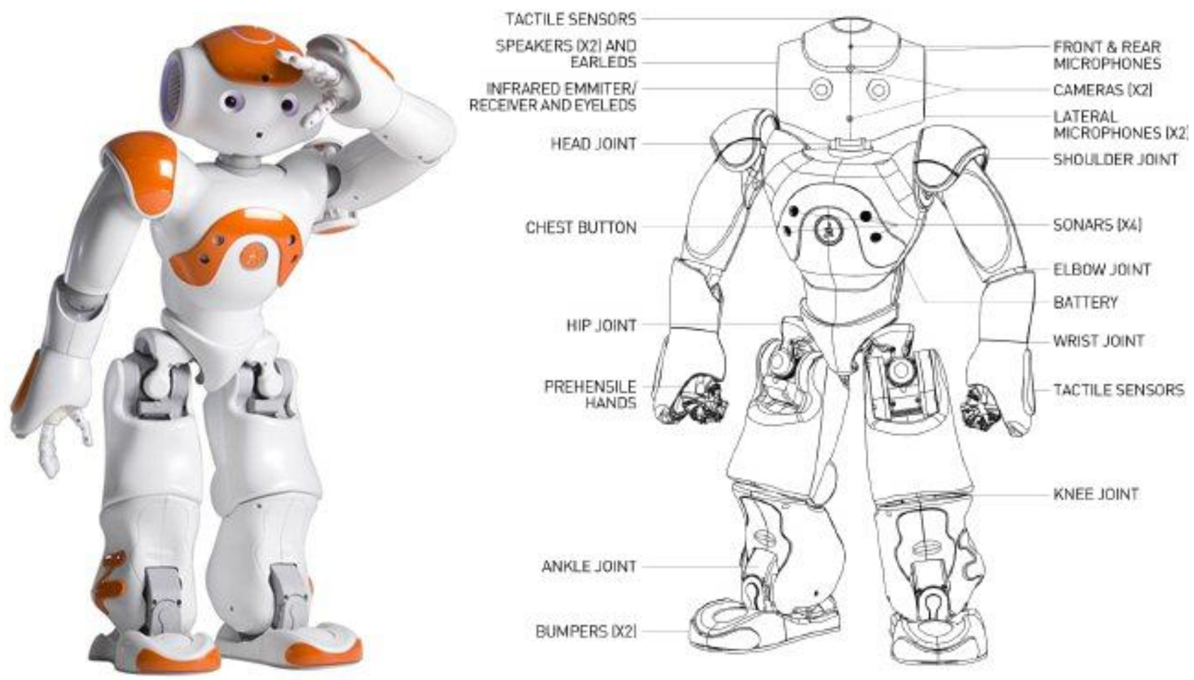

Figure 5 NAO robot

In order to appeal to the children we wanted to establish a believable background story for the robot. The background story should answer questions such as "Where does the robot come from?", "What are its goals?" and "How does it spend its days?". From the literature it was inferred that liking the interaction partner has a positive effect on self-disclosure, so it is beneficial to this study to make the robot as likeable and relatable as possible. Also, it facilitates the robot to trigger the child to talk about his/her day, reflect on how they experience their diabetes in daily life, and disclose personal information, which could be entered in the diary. The background story can be used as a guideline for drafting the robot dialogue model later on.

The robot was given a human name: *Charlie*. This name was chosen because it is both a male and female name. We wanted Charlie to be genderless because we wanted it to appeal to both girls and boys. However, Charlie was most often referred to by children as a "he", so we will proceed to do the same in the text that follows.

> ***Background story***
> *In human years Charlie is 10 years old, so he is roughly the same age as the child. Charlie plays hockey on Wednesdays and Saturdays. He also likes to play soccer with other robots. He has three siblings (Jamie, Sasha and Robin) who all look alike. In a way you could say they are quadruplets, but robots are not "born" so it's a little different from humans. His favorite color is orange, which is also the color of some of his body parts (others are white). Dogs are his favorite pets and he owns a robot dog called AIBO. Charlie's favorite school subject is Dutch. Although he feels learning the language is a bit difficult at times, he always gives it his best. Math is also interesting, but he thinks maybe that is because it is inherent to robots to like these things.*
>
> *Every day Charlie goes to a special school for robots. There he receives the necessary education to one day become a care robot. In a few months he will be able to help the doctors and nurses in the hospital to take care of diabetic children. He still has a lot to learn, so he hopes the child can help him by showing him how to keep a diabetes diary.*

Part of the background story will be shared with the children at the start of the study so that they know who they will be talking to. More details can be revealed during the subsequent interactions with the robot. We will explain more about this in the next sub section.

4.3.3 Robot dialogue model

The main function of the robot is not just explaining how the diary works, but also stimulating the child to continuously keep the diary, and evaluating the content of the diary together with the child, hopefully creating a bond between the two after a few interactions. Ultimately, the goal of the ALIZ-E project is an independent and integrated system. This requires an elaborate and structured dialogue system that can operate without the constant need for adjustments made by the experimenter. We thought it was important that the children had a good idea of who they would be talking to before the start of the experiment and that they could see the robot was a physical being, so we decided to first have a personal introduction session with Charlie during which they both got to know each other a little bit. It was not feasible to have all the children travel to TNO, so we visited the children at home, bringing the robot with us. In future sessions the children would be seeing the robot via a webcam, because the positive effects of having a physical body were shown to still be prevalent when the robot is shown remotely via a camera. Although most of the dialogue was pre-scripted, the experimenter still needed to send the commands to the robot through mouse clicks to utter a certain sentence or perform a type of behavior. We will discuss the reasons for this in sub section 4.5.2.

Introducing Charlie

At the beginning of the experiment, Charlie was introduced to each child individually at home. First, Charlie introduced himself to the child and then asked the child to do the same in return. Charlie asked about the child's name, age, hobbies and sports. This information was immediately stored in its user model with help from the experimenter. The robot also explained the goal of the study, and asked the child to help him out. The dialogue structure for the introduction session is shown in Appendix A. We will talk more about the exact procedure we followed in chapter 4.9.1.

Keeping a diary with Charlie

As we needed to have multiple interaction moments with the robot to answer our research questions, every child was scheduled to have five interaction sessions with Charlie over the course of two weeks. The interaction sessions all followed the same pattern, which is evident in the top level process shown in Figure 6. A full overview of the robot dialogue structure can be found in Appendix A.

Every session started out with what we call the "welcome process". In this process contact with the child was established. The robot greeted the child and asked about his/her feelings towards this session ("Are you looking forward to keeping your diary with me today?"). The next step in the process was logging into the diary. The robot helped the child if he/she was unable to locate the diary or had trouble logging in by giving verbal instructions. It also explained the functions and goal of the diary if the child wished to hear this information. Once contact was established and the child was logged into the diary, the robot asked the child to tell it where he/she wanted to start with filling in the diary. This ensured that the child felt in control of the situation. Depending on the choice that was made, the robot then guided the child through the process of entering the values for the chosen section of the diary until all sections were completed. Listening to the explanation of a diary section was mandatory the first time, and optionally accessible in subsequent sessions. The child could ask the robot questions at any given moment, which the robot could answer using one of the pre-scripted answers from the dialogue model. Every value the child entered was rewarded by the robot by positively confirming the value (e.g. "good job!" or "that looks great"). The robot also responded differently depending on the child's input for appetite, energy, mood and daily activities log. For example, if the child indicated that he or she was feeling down (either in the diary or verbally), the robot was sympathetic (e.g. "I'm sorry to hear that, I hope you will feel better tomorrow"). Conversely, if the child said he was feeling very energetic today the robot said for example "That is good to hear! You can never have enough energy as far as I'm concerned". When the child told the robot that he/she was done with the diary both of them said their goodbyes. The robot asked the child to fill in the questionnaire about his/her experiences of this session and told him/her to close the window. More information about the questionnaires we used can be found in 4.4.

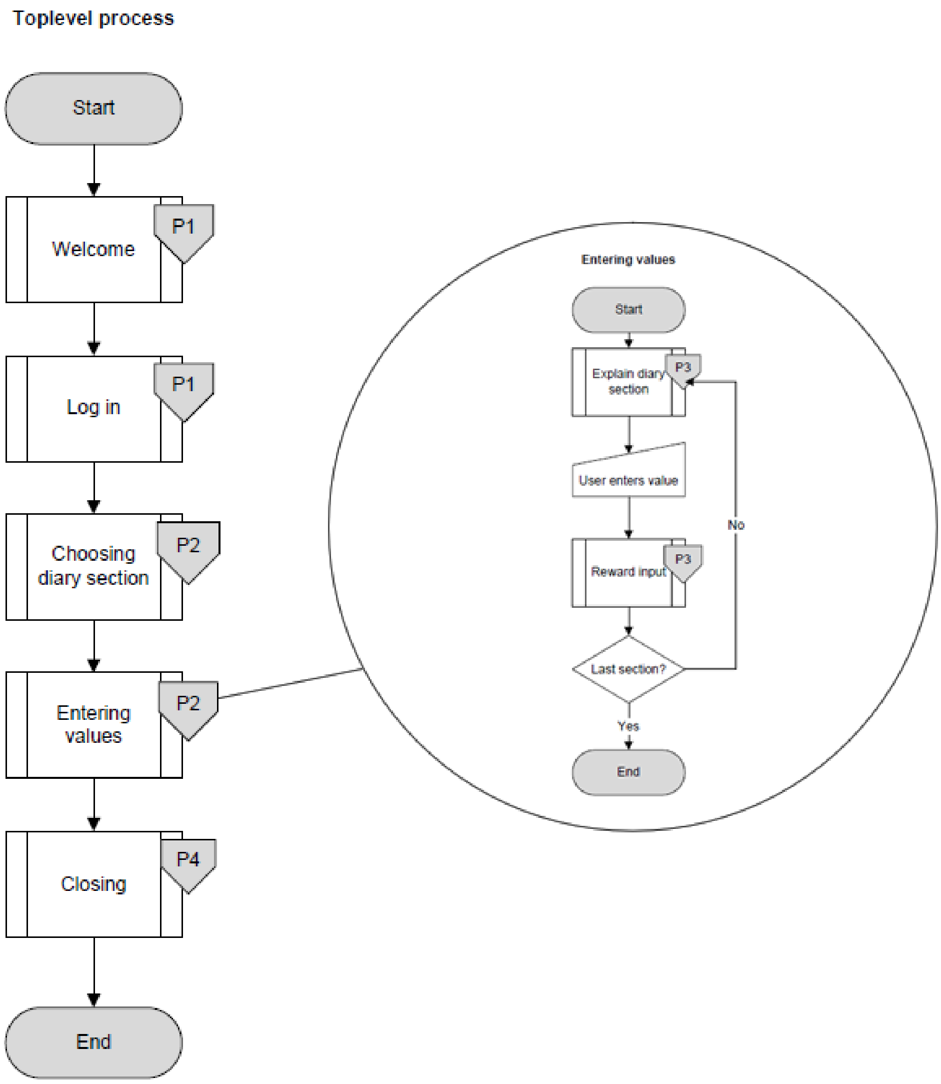

Figure 6 Top level robot dialogue showing one sub process.

Triggers

Sometimes the child or the robot will say or do something that we did not expect, or that is not directly related to the task of keeping a diary. To this end we developed some "triggers", which are sub dialogues that can be loaded by the experimenter at any given point in time. They do not occur at a set point in the dialogue process tree and are therefore shown separately from the main process (see Appendix A, P4). The experimenter could ask the child (through the robot) to adjust the microphone or webcam when there was a problem with the audio or video. Another use for the triggers was to ask the child to repeat or rephrase a statement, ask the child where he/she was stuck, or telling the child when an error had occurred that could not be solved without help from the experimenter. The latter type of triggers is referred to as *clarifying questions and comments*.

Small talk

We translated the background story to what we refer to as "small talk". In this context small talk consists of the phrases the robot uses to form a bond with the child. Essentially everything that is not directly related to supporting the task of keeping the diary is referred to as small talk. Combined with the task-related part of the dialogue, we were able to create a comprehensive dialogue structure that is flexible enough to reasonably accommodate the free-flowing nature of human dialogue. We distinguished between three types of small talk: diary-related, self-disclosure, and diabetes-related.

Diary-related small talk was used for the robot to advise or remind the child of something that has to do with the diary (e.g. "Do not forget to fill in your daily activities log"). *Self-disclosure small talk* started with the robot sharing some information about himself and optionally asking the child to do the same. For example, the robot told about its favorite pets, and then proceeded to ask the child if he/she has any pets. In the *diabetes-related small talk* the robot talked about what it learned at school about diabetes (e.g. doing sports when having diabetes) and asked the child some basic questions about this topic (e.g. how do you handle your diabetes when you do sports), and if he/she had any fears related to his/her diabetes (e.g. fear to prick blood glucose, or fear to exercise). Small talk is (mostly) pre-scripted and used by the experimenter at his/her own insight by sending the command to the robot. When a related topic is mentioned or when there is a moment of silence, the experimenter can choose to use one or more of the small talk phrases.

4.4 Instruments

4.4.1 Questionnaires

In the case of children, it is very important that the questions are clear and that they are able to understand them. To facilitate this, we used easy vocabulary, short and unambiguous questions and emoticons whenever we asked about the child's feelings towards something. We also made sure the experimenter was present during the first and final questionnaires (which were the longest) to answer any questions from the children. Seven questionnaires were administered: one pre-condition questionnaire focusing on demographic data and the respondents' expectations; one questionnaire after every interaction session (five in total) focused on experiences with the diary and the robot; and finally one post-condition questionnaire which focused more on the human-robot relationship and evaluation of the experiment. An overview of the questionnaires can be found in Table 9. The full questionnaires (in Dutch) are included in Appendix B.

Table 9 Questionnaire overview

Questionnaire	Information that was recorded	Time of measurement
Pre-condition	Demographic data and child's expectations.	Prior to the interaction sessions after receiving a brief introduction about the robot and the diary.
Interaction session (1)	Experiences with the diary and the robot.	After the first interaction session.
Interaction session (2)	See above.	After the second interaction session.
Interaction session (3)	See above.	After the third interaction session.
Interaction session (4)	See above.	After the fourth interaction session.
Interaction session (5)	See above.	After the fifth interaction session.
Post-condition	Human-robot relationship and evaluation of the experiment.	During the closing session, but prior to being debriefed about the robot's actual capabilities during the study.

4.4.2 Logs

Experimenter observation logs

After each session, the experimenter elaborated on the observations made during the interaction session. The observation log for a session was typically 5-7 lines long. The experimenter noted the presence or absence of parents, overall mood of the child, problems encountered with the robot or the diary, changes in attention, and any spontaneous social behavior towards and interaction with the robot.

Mijn Zorgpagina diary logs

Mijn Zorgpagina provided us with full logs of the diaries. Time, date and events were logged for both the sessions with and without the robot. This elicited more than 800 lines of log data on values entered into the diary (the general layout of the log is shown in Figure 7). This excluded data on the self-reported daily activities logs which was retrieved from the children's accounts by exporting their diary entries to PDF format.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	id	diary_	source	type	value	occurred_at	finished_at	device	medic	note	created_at	updated_at	deleted_at	is	value_original
2	121531	2909	manual	measurement-glucose	19.00	2012-12-10 08:30:00	NULL	NULL	NULL		2012-12-10 17:07:58	2012-12-10 17:07:58	NULL	0	0.00
3	121532	2909	manual	measurement-glucose	19.30	2012-12-10 12:30:00	NULL	NULL	NULL	toen heb ik een ding in n	2012-12-10 17:08:39	2012-12-10 17:08:39	NULL	0	0.00
4	121533	2909	manual	measurement-glucose	13.00	2012-12-10 18:00:00	NULL	NULL	NULL		2012-12-10 17:08:58	2012-12-10 17:08:58	NULL	0	0.00
5	121534	2909	manual	nutrition-carbohydrates	23.00	2012-12-10 08:30:00	NULL	NULL	NULL		2012-12-10 17:09:37	2012-12-10 17:09:37	NULL	0	0.00

Figure 7 Screenshot showing log data as provided by Mijn Zorgpagina.

Wizard of Oz logs

The Wizard of Oz (WoOz) software produced automatic logs of every command sent to NAO. There were two types of commands: *speech* and *behavior* commands. A speech command refers to any phrase that is uttered by the robot. These phrases can selected from the pre-scripted robot dialogue model, or they can be typed by the experimenter. Behavior commands constitute simple robot movements such as nodding, cheering or waving. These behaviors were mapped to specific buttons in the WoOz interface. The logs did not include anything the child said to the robot, although this can usually be inferred from the robot's response. The entries in the WoOz log are time-stamped.

4.4.3 Recordings

Every interaction session with the robot was supposed to be recorded. Unfortunately the software we used malfunctioned at the start of the experiment and we were no longer able to use it. We were only able to record 4 of the 30 sessions we had in total. We still mention it here because the few recordings that we did have do provide us with meaningful insights into the way the children interact with the robot.

4.5 Materials

4.5.1 Hardware

NAO robot

In the study we used the Next Gen V4 NAO (revision 5322). The NAO used Acapela to convert text to speech, and spoke with the Dutch female voice Femke, which was adjusted to sound somewhat more childlike and gender-neutral. The NAOqi software version was 1.12.5. Our NAO was named "Charlie". The robot was connected to the experimenter's laptop through a cable connected to a router.

Silent mouse

To operate the experiment laptop we used a Nexus Silent Mouse SM-70008. The wireless silent optical mouse lacks the "click" sound when you press the buttons. This was important in the experiment because we did not want the child to be aware of the fact that the robot was controlled by the experimenter through mouse clicks in the WoOz interface (see 4.5.2).

Laptops

We chose to supply the children with a laptop from TNO so that we could make sure that the software functioned as intended and that the laptop was not used for other purposes than keeping a diary and talking with Charlie. Each child received a Windows 7 laptop with a personal user account to use at home. This account was stripped down to the bare minimum required for the experiment. Children had no administrative privileges and could only use their internet browser (Google Chrome) to fill in the online diary and connect with NAO using TeamViewer. A text file with the child's login data for the diary was provided for added convenience and located on the desktop.

Each laptop was equipped with a separate mouse and webcam. Laptops were connected to the internet using a wired or wireless internet connection (depending on availability) which was tested on-site to make sure it worked.

4.5.2 Software

Wizard of Oz interface

The children interacted with the robot which they believed to be autonomous, but which was actually controlled by the author of this thesis. We call this a Wizard of Oz (WoOz) setup. This method was particularly suited for our needs because only a few actions could be performed by NAO autonomously, such as movements while speaking, 'blinking' of the eyes and speaking (TTS). Other actions could not be performed autonomously and needed a human in the loop. These were:

- Understanding user input (speech, gestures, and actions);
- Choosing the right remarks and (sub) dialogues;
- Responding to unexpected user input that is not part of the structured dialogue;
- Making certain movements such as cheering or nodding;
- Updating the user model.

To support this type of experiment, we adapted a WoOz interface that was already developed for use in the ALIZ-E project to support the added functionality. In Figure 8 the full setup is shown. The interface was divided into several different screens, each with its own function.

- **Red (left):** The Dialogue Composer was used to send speech commands to NAO. Dialogue files (XML files with .dialogue extension) can be loaded at the top. The experimenter could then navigate through the dialogue by clicking the sub dialogues (if there were any). To send a string, the experimenter clicked the Send button. The experimenter could also choose to skip strings if desired. Located at the bottom of the dialogue composer was the small talk.
- **Green (top center):** The NAO Client was used to check whether or not NAO was connected. There were also four buttons for NAO expressions included in this part of the interface: nodding and shaking its

head, waving, and a gesture we called ‘success’ (waving both arms in the air as a sign of happiness or enthusiasm).

- **Purple (center):** Diary ‘panic buttons’ were used in case the experimenter did not understand the child, or if the experimenter noticed the child did not understand the robot. The buttons could also be used to tell the child to focus a little while longer on the task, or to tell the child that a critical error has occurred. Every button held about 3-4 random phrases that had the same meaning, so that when a button was clicked a second time, the robot did not say the same thing twice.
- **Orange (bottom center):** The User Model stored information such as user ID, name, age, hobbies and weight.
- **Blue (right):** The Game Manager was used to load the various components (dialogue composer, NAOClient, UserModel and Panic buttons). Any output from the robot such as sounds or movements was logged in the bottom half of this screen.

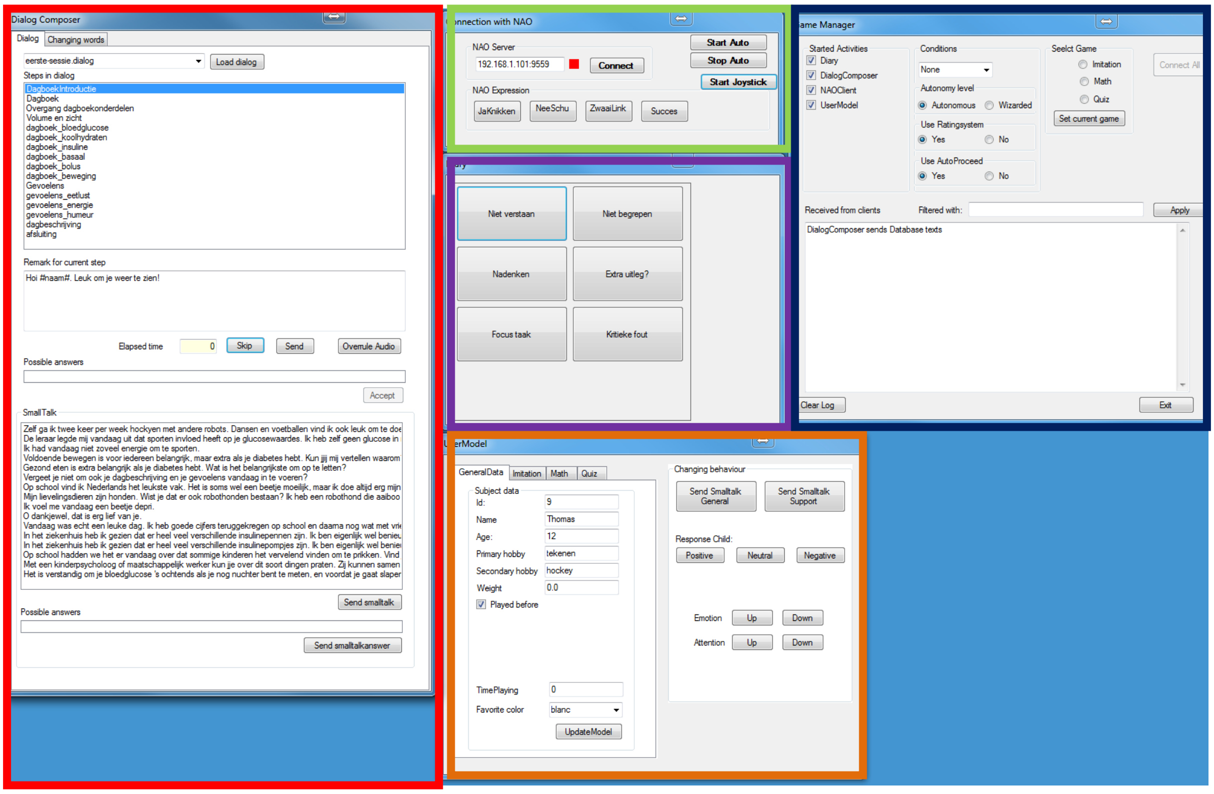

Figure 8 Wizard of Oz interface

ZD Soft Screen Recorder

ZD Soft Screen Recorder is a screen recording software program. It allows for clear recording of the entire computer screen, as well as incoming and outgoing audio. This particular software was chosen for its easy to use wizard-like interface and smooth recording without lagging the system.

TeamViewer

TeamViewer is a proprietary computer software package for remote control, desktop sharing, online meetings, web conferencing and file transfer between computers. However, in this experiment only the desktop sharing and meeting functionalities were used. We created a user account for every child and set it up so that it would automatically log in when there was an internet connection. Upon opening TeamViewer the child saw a contact list with Charlie's name on it. A green dot indicated Charlie was online, a grey dot meant he was offline (or rather, the experimenter was offline). All the child had to do was invite Charlie to share screens at times that were agreed upon during the introduction session.

4.5.3 User manuals

To avoid a situation where the child does not know what to do, we supplied the children with a full-color manual with instructions on how to log in on the laptop and the diary. Also included were instructions on how to connect with Charlie. The manual was filled with screenshots and written in a child-friendly way. The full user manual (in Dutch) can be found in Appendix C.

4.6 Experimental design

For the experiment, a within-subjects design with two conditions was used. The two conditions were: keeping the diabetes diary *with* the robot (5 sessions), and keeping the diabetes diary *without* the robot (6 sessions). We made two groups of three participants to spread the workload. Group 1 (uneven numbers) started on day 1 with the robot and had their last session on day 11. Group 2 (even numbers) started on day 2 and had their last session on day 12. The first and last diary sessions were always with the robot. On the days in between, the condition alternated every day. This excluded the weekends which were always without the robot because the experimenter had no access to the facility. In Table 10 the participant planning is shown. The sessions were carried out from the comfort of the participant's own home using remote desktop sharing software and video conferencing to contact the robot. As stated before, the robot was semi-controlled by the experimenter through a Wizard of Oz interface.

Table 10 Participant planning for interaction sessions with robot

Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Round 1	PP3	PP2	PP3	PP6	PP3			PP2	PP3	PP2	PP3	PP2
Round 2	PP1	PP4	PP1	PP4	PP1	Weekend		PP4	PP1	PP4	PP1	PP4
Round 3	PP5	PP6	PP5	PP2	PP5			PP6	PP5	PP6	PP5	PP6

A session with the robot lasted approximately 10-15 minutes. The first session typically took a bit longer than the other sessions because it also included explanations of the diary sub sections.

We used both quantitative and qualitative data collection methods because the sample size (N=6) was not large enough to draw any strong conclusions solely based on quantitative data. Quantitative data was gathered from the website log data from Mijn Zorgpagina, the questionnaires that were administered, and the experimenter observation logs. Instead of relying solely on statistical analysis, we also included observations made by the experimenter to explain and comprehend the research findings.

4.7 Experimental setup

The interaction sessions of the experiment took place at TNO, in one of the labs in the Experium. As we stated before, the children connected with the robot through video conferencing software from their own home. They were free to choose where they wished to be seated during the session. As illustrated in Figure 9, the robot sat in a chair on the desk. The webcam was aimed at the robot from an angle slightly higher than eye level (see Figure 10). We chose this setup because it mimics the natural sitting position of humans during video calls. Usually, the webcam is located at the top of the laptop or desktop screen, so we did the same for Charlie as we wanted the participants to believe he was operating his own laptop.

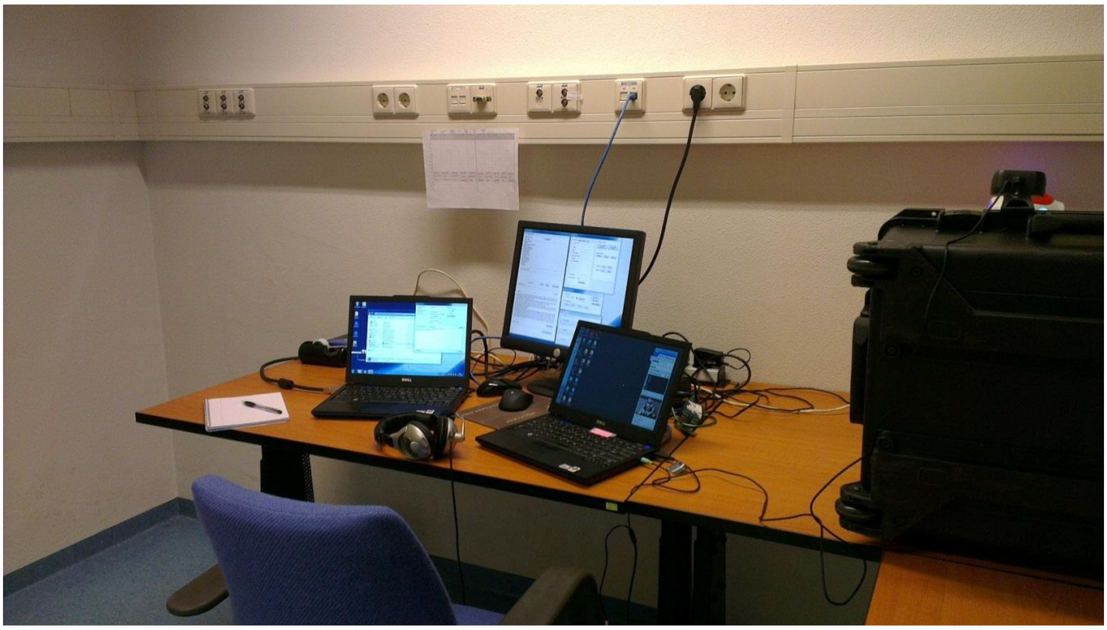

Figure 9 Experimental setup (laptops).

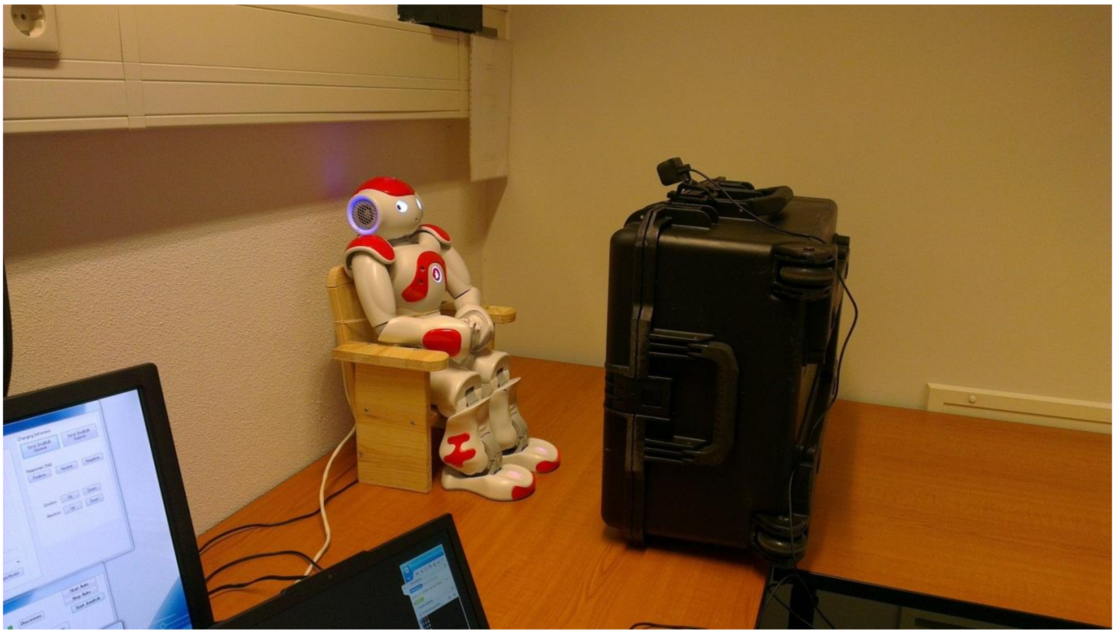

Figure 10 Experimental setup (robot and webcam).

In Figure 11 the screen as seen by the child is shown. We see the diary taking up most of the screen, with the webcam feeds on the right hand side of the screen. The experimenter was seated out of view and made as little noise as possible so as not to alert the child to her presence. The silent mouse was particularly useful to this end.

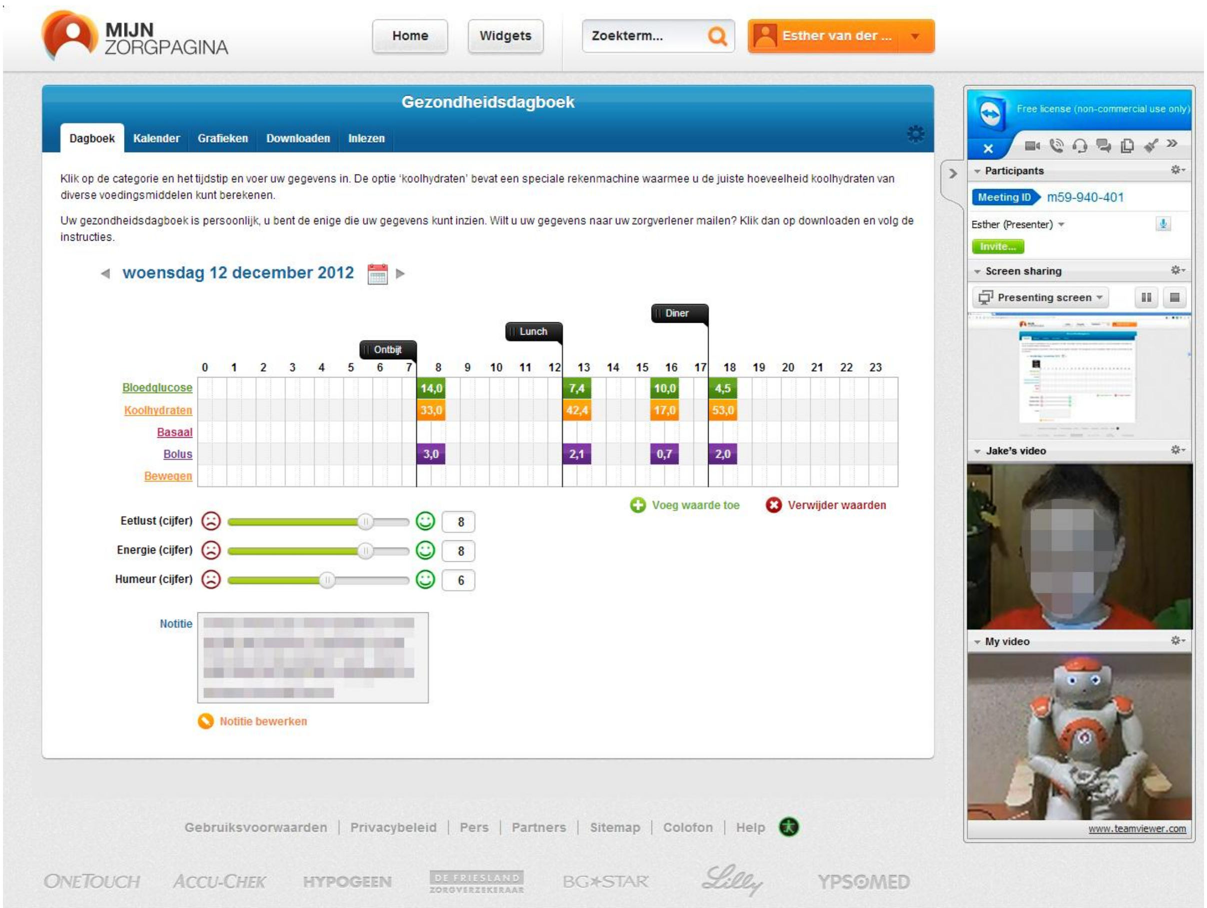

Figure 11 Screen as seen by the child (face and daily activities log blurred for privacy reasons).

4.8 Measures

In chapter 3 we defined three sub research questions. In this chapter we will describe per question how it was measured.

4.8.1 Adherence

The first question we asked was: *how does communicating with the robot while filling in the diary help improve children's diary adherence?*

Adherence in this context may be defined as the extent to which the children keep an accurate account of their values, mood and activities in their diaries on time (meaning on the same day the values were measured).

In order to be able to say that something has improved, we first need to know what the situation was like before the intervention. As a pretest, we asked the children to fill in a questionnaire at the start of the experiment. One of the questions was about their current diary adherence. Other questions elicited their expectations of the diary, the robot and the experiment to determine what they expected to gain from the experience.

By logging the use of the children's diaries with the help of Mijn Zorgpagina, we were able to tell when the children logged in, and what information they entered into their diaries. Because of the timestamps on the log data and the WoOz logs, we could tell exactly when the robot had been present. This information was then used to determine the difference between the days they kept the diary with the robot and days they kept it by themselves. We could also tell from the logs when the children had supplemented their diaries with extra information. If the robot truly has a positive effect on diary adherence, we expect to see more completed diary entries with the robot, as well as more supplementary behaviors.

Another measure we used to determine diary adherence as well as bonding was the amount of experience sharing between the child and the robot. Self-disclosure is an act of trust and friendship, so when the child shares a personal story or experience with the robot, he/she must be bonding with it. Unique about the diary in this study is that it was not limited to factual information, but it also included an opportunity to share subjective experiences and emotions. We compared the amount of data that was entered in the diary when the robot was present, with the data on days the robot was absent, by counting the amount of characters used in the self-reported daily activities log.

The children were asked to fill in a questionnaire after each session with the robot. The question we asked that was relevant to measuring diary adherence, was asking the child to give a rating to the diary for that session. While not directly an indicator of adherence, it does tell us how positive or negative the diary was experienced. So if there is a sudden change in diary adherence, we can determine if this was affected by attitude towards the diary.

4.8.2 Engagement

The second research question was: *how engaged are the children with their diaries when they interact with a robot?*

An engaged child spends more time on the diary, is focused on the task, and takes an active role in the activity. If we measure the time the children spend on their diaries, this tells us something about their level of engagement. It is easy to calculate how long the interaction sessions took by noting the start and end-times of each session in the WoOz logs. This was done automatically, so it required little effort on our part.

Active participation was measured on a subjective level by the experimenter in the observation logs. Initially we wanted to record all the sessions and annotate them later; but since we had technological difficulties, we had to make do with the logs. A child was thought to take an active role when whenever he/she asked or told the robot something out of his/her own initiative instead of waiting for the robot to make the first move. Active participation means taking a proactive rather than a passive role in the conversation.

Attention can be measured by monitoring how the child behaves while filling in the diary, once again using the experimenter logs to record the data. When the child looks away or his/her attention shifts to a different topic, task or person, attention is fading. However, when the child looks mostly at the robot and the diary, he/she is much more attentive.

4.8.3 Bonding

The third question concerned the bond between the child and the robot: *how does the relationship between the child and the robot evolve over time?*

A bond between two entities is characterized by emotions such as affection and trust. The bond between a child and the robot created increases levels of engagement and can have positive effects on the child's adherence, thus acting like glue that binds everything together. To track changes over time, we needed to take measurements during the course of the experiment, not just at the beginning and the end. To this end, we chose to have the children rate the robot after each interaction session, and to have them fill in a questionnaire at the very end. The questionnaire at the end focused on the degree of relatedness the child experienced with the robot. When a child trusts the robot, believes it has feelings, and thinks that it can truly understand the child, the feeling of relatedness is strong.

Children could choose to either type their experiences in the diary, verbally express them, or both. In the experimenter logs we noted the subjective level of experience sharing that was done verbally.

In Table 11 we provide an overview of the measures and instruments we used to gather our data.

Table 11 Overview of measures, instruments and data

Measure	**Instrument**	**Data gathered**
Adherence	Pre-condition questionnaire	Demographic information; interest in technology; current diary adherence; expectations of the diary, robot and experiment
	Mijn Zorgpagina diary logs	Completed, missing, supplemented and later completed diary entries; characters in self-reported daily activity logs
	Interaction sessions questionnaires	Diary ratings
Engagement	Experimenter logs	Active participation; attention
	Recordings	Active participation; attention
	WoOz logs	Time spent on diary
	Mijn Zorgpagina logs	Time spent on diary
Bonding	Interaction sessions questionnaires	Robot ratings
	Post-condition questionnaire	Robot and diary ratings; degree of relatedness, feelings towards robot
	Experimenter logs	Experience sharing

4.9 Procedure

4.9.1 Introduction sessions

Six diabetic children were recruited from Ziekenhuis Rivierenland Tiel (hospital) to participate in the experiment. Eligible children received an information package by mail that was sent via the hospital and were invited to participate. There was a form included that when signed and returned by the parents, allowed us to contact the parents about the experiment. We made appointments with the families to visit their homes in the next week to deliver the necessary materials and to carry out the introduction session with the robot. The introduction sessions took place one week before the actual experiment.

1. First we introduced ourselves to the child and its parents. We explained the goal of the research and the experiment and introduction session procedure. Parents and children could ask us any questions they had. We then had one of the parents sign the consent form while we set up the robot and the laptop according to the technical protocol in Appendix D;
2. Once the child was ready, we let the robot introduce itself to the child as Charlie. After briefly exchanging names and hobbies, Charlie explained how he wanted to help the child keep a diabetes diary;
3. The experimenter then took over again and retrieved the laptop designated for the child;
4. After establishing an internet connection, the experimenter explained to the child how to log in and how to start the diary. The child was told that this information could also be found in the manual;
5. Together the experimenter and the child filled in the personal data (name, age, diagnosis, treatment);
6. We then started and tested TeamViewer together to interact with Charlie;
7. After all the technicalities were taken care of, we asked the child to fill in the pre-condition questionnaire. We also scheduled appointments for the interaction sessions and an appointment to pick up the materials once the experiment was over;
8. A picture with Charlie and the child was taken for the certificate they would later receive as their reward;
9. The child and their parent(s) were thanked for their cooperation.

4.9.2 Interaction session

Over a period of two weeks a total of 30 interaction sessions (5 per child, 6 children in total) were carried out with the robot. The experimenter was located in an experiment room at TNO. The participants were able to carry out the tasks from home using the laptops and webcams they received. The sessions took place after school hours, between 4 and 7 PM.

1. First we connected the robot and the laptops according to the technical protocol listed in Appendix D. Once everything had been set up, we were ready to start the interaction session with the child;
2. When the child was ready to fill in the diary he/she contacted Charlie using TeamViewer. The experimenter accepted the invitation to start the session. Both participants turned on their webcam and microphone in order to be able to talk to each other;
3. The robot greeted the child and asked the child to log in if it had not already done so;

4. Together Charlie and the child filled in the diary sections until all sections have been completed. The robot responded to the input of the child at the appropriate times, showing emotions such as gratitude, compassion and understanding through its speech and behavior;
5. Once the child indicated he/she was done with the diary, the robot initiated the closing procedure. It asked the child to fill in a questionnaire and waved goodbye to the child;
6. After closing TeamViewer, the child filled in the printed out questionnaire on its own.

4.9.3 Closing session

After the interaction sessions we scheduled a final appointment to thank and reward the participants, and to collect the materials.

1. The experimenter brought the final paper questionnaire and asked the child to answer the questions;
2. The children and the parents were debriefed about the robot's actual capabilities during the study (it was not able to understand anything the child said, the experimenter was in control);
3. The certificate with a photo of the child and the robot was handed out to the child, along with a gift certificate for a toy store;
4. Both the child and the parent(s) were thanked for their cooperation and participation;
5. The material (laptop, webcam, internet cable, completed questionnaires) was collected and brought back to TNO.

4.9.4 Ethical considerations

As the participants in this study were young children suffering from a medical condition, certain ethical issues needed to be addressed. The consideration of these ethical issues was necessary to ensure the privacy and safety of the participants. TNO's Review Committee for Test Subject Experiments (Toetsings-Commissie Proefpersoon-Experimenten) agreed that the ethical issues listed below were sufficiently addressed in this study and that no further involvement from the Medical Ethical Committee (Medisch Ethische Toetingscommissie) was necessary (L. Toet, personal communication, August 9, 2012).

Consent

All participants and their parents were carefully informed of the details of the study, including its aim and purpose. They were told that they could withdraw from the study at any time. Both participants and one of their parents signed consent forms.

Confidentiality

The confidentiality of the participants was ensured by not disclosing their names or personal information in the documentation of this research. Only relevant details that helped in answering the research questions were included. In principle the data entered in the diary was not shared with parents or guardians because for the purposes of this study it was important that the participants' trust in the robot remained as large as possible. Sharing private information could potentially compromise the trust relationship. However, prior to the experiment it was discussed with the participants and their parents that in the event that any information surfaces that could have consequences for the treatment of the child, the experimenter can choose to share this information with a diabetes nurse, pediatrician or physician. It was up to the experimenter to determine which information this concerned.

Medical authority

The experimenter is not a healthcare professional, so the robot that was being controlled by the experimenter could not make any statements or inferences about good or bad values entered into the diary. The robot was only allowed to make statements about diary adherence, provide information about the diary, or engage in small talk with the child.

4.10 Summary

Six children in the ages of 9 to 12 suffering from diabetes type 1 participated in this experiment. They were split into two groups of three because there was not enough time to host interaction sessions with all of them on the same day. All children kept a diary for eleven days; the starting date for group 2 was one day later than group 1. Every other day the children filled in their values together with the robot. They did this after school hours at home. There were no interaction sessions in the weekends. In total there were five sessions with the robot, and six without the robot. The robot was located at TNO and controlled by the experimenter in a Wizard of Oz type of experiment. The children were able to contact the robot using the laptops and software we provided. They kept an online diary on www.mijnzorgpagina.nl. The diary on this website was adapted for use in the experiment. A dialogue model was created for the robot to guide the children through the process of keeping a diary, and for having a conversation with the children. The goals were to find out if the robot was beneficial to the children's diary adherence, if keeping a diary with the robot was engaging, and how the relationship between them evolved over time. Before, during and after the experiment the children answered a questionnaire. We also kept logs of their diaries and interactions.

5 Results & analysis

In this chapter we will present the results of our experiment. We will start out by briefly addressing the data processing techniques that were used to prepare and process the data we obtained from the various research instruments. Next, we go over each of the measures, starting with adherence, then moving onto engagement and lastly bonding. Finally, we list any observations and results that were not specific to any of the measures, but that could have been of influence in the experiment.

5.1 Data processing

5.1.1 Software

We used IBM's Statistical Package for the Social Sciences (SPSS) 20 for all calculations and most of the visualizations of the data obtained from the questionnaires. In one instance (time spent on diary over time) we had to make use of Adobe Photoshop to plot the different lines in the same graph.

5.1.2 Pre-condition questionnaire

The pre-condition questionnaire was answered before the start of the actual experiment. It consisted of open ended, scaled, multiple choice and word association questions. Its main focus was on the children's demographic data and expectations of the robot, the diary, and the experiment. It was used in part for answering the research question we had about diary adherence. A breakdown of the pre-condition questionnaire is shown in Table 12.

Table 12 Pre-condition questionnaire breakdown

Question	Type	Processing
Name	Open ended	-
Age	Open ended	Calculated youngest, oldest, mean, std. deviation
Year of diagnosis	Open ended	Calculated earliest, latest, mean, std. deviation
Family members with diabetes	Open ended	Converted to yes or no
Interest in technology	Scaled (1-4)	Calculated mean, std. deviation
Diary responsibility	Multiple choice (4)	Counted frequency
Diary adherence	Open ended	Interpreted answers
Expectations of online diary	Word association (8)	Tabulated answers
Expectations of robot	Open ended	Tabulated answers
Expectations of experiment	Scaled (1-3)	Calculated mean, std. deviation

5.1.3 Interaction session questionnaires

The interaction session questionnaires consisted of only two scaled questions. The children filled in the questionnaire after every interaction session with the robot. Its focus was on measuring changes over time in the children's experiences of the robot and the diary. We used the ratings we gained to partly answer the research questions we had about diary adherence and bonding between the child and the robot. A breakdown of the interaction session questionnaires is shown in Table 13.

Table 13 Interaction session questionnaire breakdown

Question	Type	Processing
Robot rating	Scaled (1-5)	Calculated mean, calculated decrease, plotted mean ratings, plotted 95% confidence interval
Diary rating	Scaled (1-5)	Calculated mean, calculated decrease, plotted mean ratings, plotted 95% confidence interval

5.1.4 Post-condition questionnaire

The post-condition questionnaire was administered after all the interaction sessions had finished. It consisted of mostly scaled questions, as well as a few open ended, word association and multiple choice questions. Its focus was on gaining insight into the child's opinion of the robot and its connection to the diary. The answers were used as an indicator for the relationship between the child and the robot. In Table 14 we provide a breakdown of the post-condition questionnaire.

Table 14 Post-condition questionnaire breakdown

Question	Type	Processing
Robot rating	Scaled (1-5)	Calculated mean, std. deviation
Diary rating	Scaled (1-5)	Calculated mean, std. deviation
Robot gender	Multiple choice (4)	Counted frequency
Understandability of robot	Scaled (1-5)	Calculated min, max, mean, std. deviation
Feelings of robot	Scaled (1-5)	Calculated min, max, mean, std. deviation
Understanding of robot	Scaled (1-5)	Calculated min, max, mean, std. deviation
Trust in robot	Scaled (1-5)	Calculated min, max, mean, std. deviation
Human-like behavior of robot	Scaled (1-5)	Calculated min, max, mean, std. deviation
Bond with robot	Word association (6)	Calculated min, max, mean, std. deviation
Ease of keeping diary	Scaled (1-5)	Calculated min, max, mean, std. deviation
Focusing on diary with robot present	Scaled (1-5)	Calculated min, max, mean, std. deviation
Helpfulness of robot in keeping diary	Scaled (1-5)	Calculated min, max, mean, std. deviation
Positive aspects of robot	Open ended	Interpreted answers
Negative aspects of robot	Open ended	Interpreted answers

5.1.5 Mijn Zorgpagina diary logs

Mijn Zorgpagina provided us with the full log data of the diaries that were completed over the course of this experiment. The logs held the following information: user id, type of value entered, time entered, time updated (or deleted), and the actual value that was entered. The only information that was missing from these logs was data on the self-reported daily activities. There were no records of the start and end times for these values.

We manually compared the data we obtained from the Mijn Zorgpagina logs with the WoOz logs and participant planning to identify when the robot had been present or absent. We were then able to determine when a diary entry had been completed, was missing, was supplemented with extra information at a later time, or when the children filled in the diary at another time than scheduled. This information could then be used to answer the question about diary adherence.

From the start and end times we were able to infer just how long a session with or without the robot had taken. However, as we stated before, this does not include the time spent on filling in the daily activities log. Because this information was lacking, we could not test if the difference in time spent on the diary was significant. However, the total time spent does give somewhat of an indication of how engaged the children were.

To determine whether there was a difference in experience sharing (an indicator for adherence and bonding) we counted the amount of characters in the logs. We first exported the diaries to PDF format, and then the notes - which hold a self-reported record of the child's daily activities-, were copy pasted to Microsoft Word. We then counted the amount of characters without spaces for each entry in the diary and added them together (for both conditions with and without robot). Then we divided the total characters by the number of sessions because there were more sessions without the robot (N=6) than with the robot (N=5). In order to determine whether the difference was significant, we used a paired-samples t-test. We also distinguished between three distinct types of participants based on this data.

5.1.6 Recordings

We only managed to record four out of the thirty sessions that we had due to an unfortunate technical issue. Whenever we started the screen recording software before a connection with TeamViewer had been established, the whole setup crashed. The only way around this was starting TeamViewer *before* the recording software. But because it took so long for this software to start up, this was hardly an option. The child would have to wait about half a minute watching the robot sit there in silence as the software started up. Because we felt this took away from the authenticity of the robot, we stopped recording this way.

5.1.7 Experimenter logs

Because the plan to record all sessions failed, we came to rely more heavily on the experimenter observation logs for information regarding the engagement of the children. The experimenter noted if there was a parent present supervising the child, what the overall impression of the session was, how actively the child participated in the conversation, and any peculiarities with respect to the diary and the robot. A word of caution is advised when interpreting these results as these observations are always colored by the experimenter's impressions of the situation and do not always represent the facts.

5.1.8 Wizard of Oz logs

In the automatically generated WoOz logs the exact start and end times of each interaction session was logged. From this information we were able to tell how long each session took, which was an indicator for engagement.

5.2 Current situation and expectations of the children

From the pre-condition questionnaire we gathered background information on the children that were participating in the experiment. We were interested in their current use of diabetes diaries, and their expectations of the diary, robot and the experiment.

5.2.1 Current situation

Five out of six children used an insulin pump and three of them indicated that they did not keep a diabetes diary (anymore) because they were able to read out values from their pumps if needed. An insulin pump delivers insulin 24 hours a day through a catheter placed under the skin. Pumps usually keep a record of blood glucose values that were measured and insulin doses that were administered, so these values are freely accessible. Only one child said that he kept the diary himself, but he also stated he only did so once every three months when it was required for a hospital consultation. After that he neglected to keep one. Two children said their parents kept the diary for them, or at least helped them significantly in doing so.

On a scale of 1 (not interested at all) through 4 (very interested), the children scored an average of 3.83 (SD = 0.41) on interest in technological advances such as robots or gadgets.

5.2.2 Expectations

During the introduction session, the children were shown the digital diary. They were then asked to choose the words from a list best describing their expectations of keeping a digital diary versus a traditional paper diary. All children indicated it would be more fun to keep their diary this way, half of them also said it would be easier and nicer. One child said it would probably be slower than keeping one on paper. No one thought keeping a digital diary would be quicker, harder or more tedious than a paper diary. None of the children picked the 'no difference' option. An overview of the expectations of the children is shown in Table 15.

Table 15 Overview of expectations of a digital versus a paper diabetes diary

Using a digital diary is:	Number of children
More fun	6
Easier	3
Nicer	3
Slower	1
Quicker	-
Harder	-
More tedious	-
No difference	-

The children were introduced to the robot and received information about the robot and the diary. They were then asked to note their expectations of the robot in an open question ("What do you think Charlie can or will do?"). Four children said the robot could explain to them how the diary works and help them keep their diary. One child mentioned the robot would make keeping the diary more fun and that it would talk with them about the diary and their daily activities and ask them questions. An overview of the responses we received is shown in Table 16.

Table 16 Children's responses to the question what the robot can or will do

Response	Number of children
Helping me keep my diary	2
Explain how to keep my diary	2
Make keeping my diary more fun	1
Talk with me about my diary	1
Talk with me about the things I've done	1
Ask me questions	1
I do not know	1

On a scale of 1 (not looking forward) through 3 (looking forward), the children all scored a 3 on how much they were looking forward to participating in the experiment.

5.3 Adherence

Diary adherence is defined in terms of the extent to which diary entries are completed on the same day as the values were measured. We obtained this data from the diary logs. We also inquired about the children's view of the diary after each session with the robot by means of a questionnaire to see how their opinion of it changed over time.

5.3.1 Diary completion

The log data provided by Mijn Zorgpagina revealed that not all children completed their diaries on time (meaning on the same day the values were measured). Occasionally, they would complete their diary at a later point in time (usually the day after), we will refer to this as *later completed entries*. Another observation was that some children go back to previous diary entries to supplement the data, we call these entries *supplemented entries*. Two children sometimes did not complete a diary entry at all. In Figure 12 it is clear that there were more fully completed diary entries with the robot than without the robot. The number of supplemented entries was roughly equal for both conditions. The number of later completed diary entries or lack of entries was larger in the condition without the robot. A paired-samples t-test was conducted to compare the number of actions performed in both conditions. There were no significant differences in the first three categories. Fully completed with robot ($M = 5.00$, $SD = 0.00$) and without the robot ($M = 3.50$, $SD = 2.26$); $t(5) = 1.63$, $p = .165$. Supplemented with robot ($M = 1.00$, $SD = 1.55$) and without the robot ($M = .83$, $SD = 1.60$); $t(5) = 1.00$, $p = .363$. Later completed with robot ($M = .33$, $SD = .52$) and without the robot ($M = .83$, $SD = .98$); $t(5) = -1.17$, $p = .296$.

However, there was a significant difference between diary entries left uncompleted with the robot ($M = 0.00$, $SD = 0.00$) and diary entries left uncompleted without the robot ($M = 2.33$, $SD = 2.16$); $t(5) = -2.65$, $p = .046$.

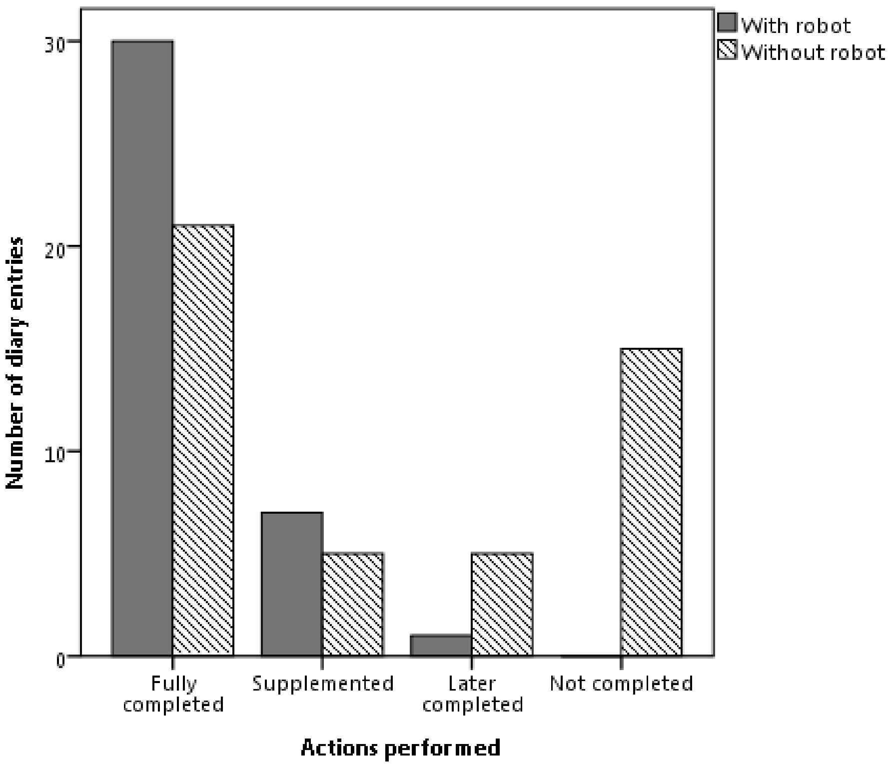

Figure 12 Diary actions with and without robot

5.3.2 Self-reported daily activities

The total amount of characters in the daily activity logs of the children was calculated per person, differentiating between the sessions with and without the robot. Taking into account the fact that there were fewer sessions with the robot (5) than without the robot (6) and thus averaging the characters per session, the averages were also calculated. The results are displayed in Table 17.

Table 17 Total amount of characters in daily activities logs

Participant	With robot	Without robot	With robot (avg.)	Without robot (avg.)
1	302	0	60,4	0
2	183	94	36,6	15,7
3	432	81	86,4	13,5
4	394	0	78,8	0
5	828	846	165,6	141
6	354	305	70,8	50,8
Mean	**415,5**	**221**	**83,1**	**36,8**
SD	**200,67**	**297,52**	**40,13**	**49,58**

Two children did not log their daily activity on the days without the robot. From the table we can distinguish three types of children:

1. Children who consistently filled in high quantities of data in their daily activity logs regardless of the presence or absence of the robot (5, 6);

2. Children who filled in less (-50% or more) on days without the robot (2, 3);
3. Children who did not fill in their daily activity on days without the robot (1, 4).

A paired-samples t-test was conducted to compare the amount of characters used in daily activity logs in with the robot and without the robot conditions. There was a significant difference in the amount of characters with the robot (*M* = 83.10, *SD* = 43.96) and without the robot (*M* = 36.8, *SD* = 54.31) conditions; t(5) = 4.13, p = .009.

Figure 13 shows a boxplot of the values for both conditions. There were two instances (data points 47 and 50) in which we found a high quantity of data despite the absence of the robot. These instances are marked as outliers in the figure below.

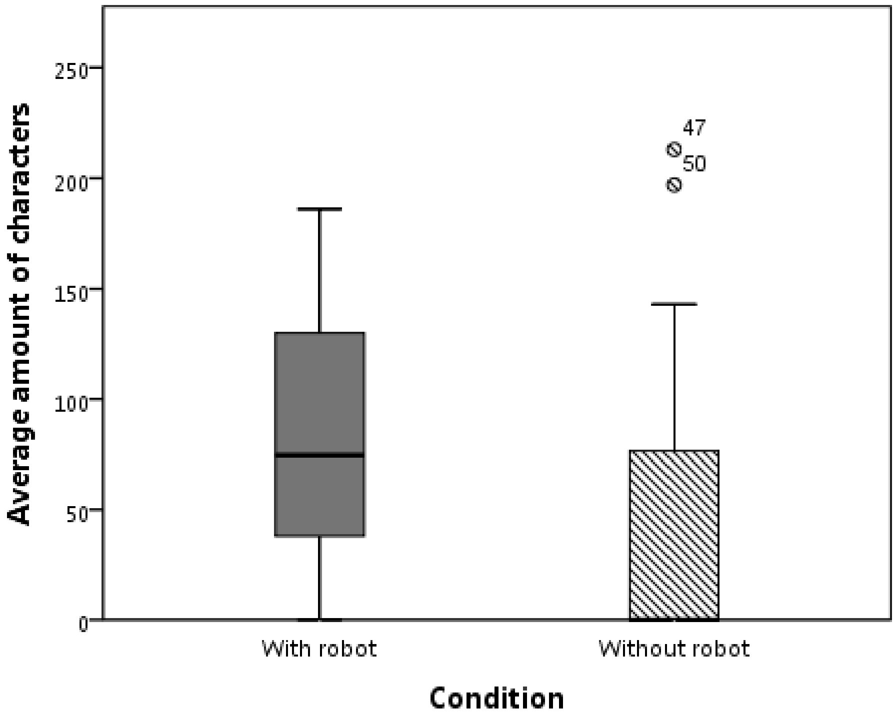

Figure 13 Total average amount of characters in daily activity logs

5.3.3 Diary ratings

After each interaction session, the children answered a short questionnaire about the robot and the diary. Figure 14 displays how the children rated the diary over time (we will come back to the ratings of the robot in a short while). Figure 14 also shows the 95% confidence interval of the ratings. The confidence interval tells us how certain we can be that the answers provided by our sample reflect the entire population of diabetic children. In this figure, a rating of 1 means the child thought the diary was absolutely horrible and a rating of 5 means the child thought it was amazing. The diary received an average rating of 3.9. There was a decrease in the ratings halfway through the experiment (from 3.67 to 3.00). After the third session the ratings increased again to roughly their initial values.

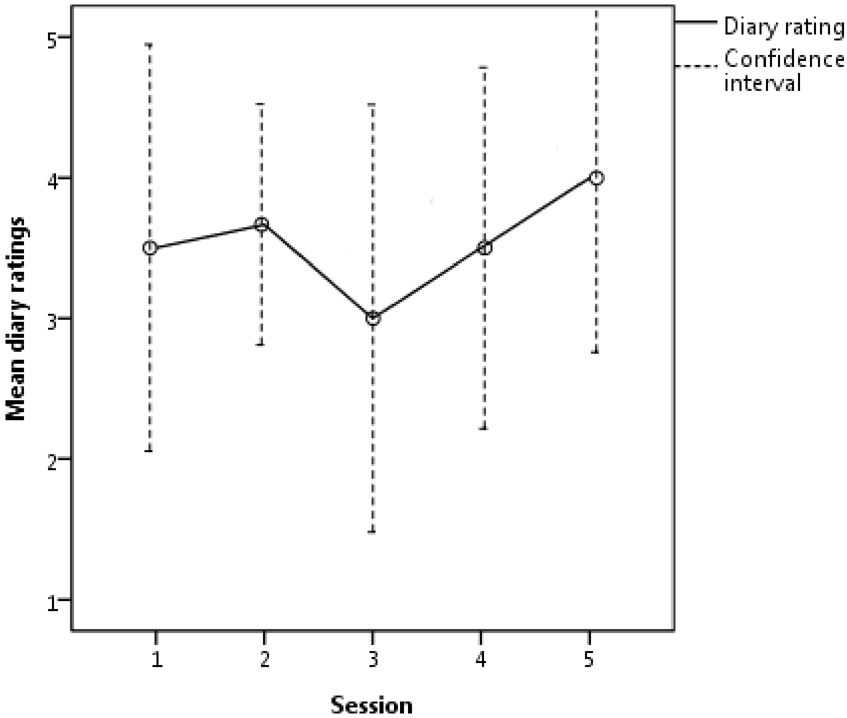

Figure 14 Average ratings given by the children for the diary and 95% confidence interval of ratings.

5.4 Engagement

Engagement was defined in terms of the time spent on the diary and the level of active participation and attention. We would expect an engaged child to spend more time on the activity, show initiative to interact and be attentive towards the robot and the diary.

5.4.1 Time spent on diary

The user logs provided by Mijn Zorgpagina held log data about measurement values, meal times and emotion ratings. Unfortunately, the logs did not include the time spent on the daily activities log. This means that we were unable to accurately determine the total time spent on the diary when the robot was not present. However, we predict that the time taken would be roughly the same. Comparing the average time it took any one child to keep a diary with and without the robot, it took them an average time of 01:12 minutes longer to do so with the robot. Judging from our experience with the interaction sessions, we think the children would spend roughly the same time in the condition without the robot. But again, we were unable confirm this because of the inequality of the data.

We were curious to see how the amount of time spent on the diary changed over time. Because there were two groups of participants interacting with the robot on alternating days, we cannot plot a straight line to show the time lapse of the time spent on the diary. Group 1 had three sessions with the robot in the first week, then another two in the second week (3-2 sessions). For group 2 exactly the opposite is true (2-3 sessions). The average time needed to complete filling in the basic values in the diary decreased from 11:19 minutes to 4:03 minutes (first and last sessions respectively), as visualized in Figure 15.

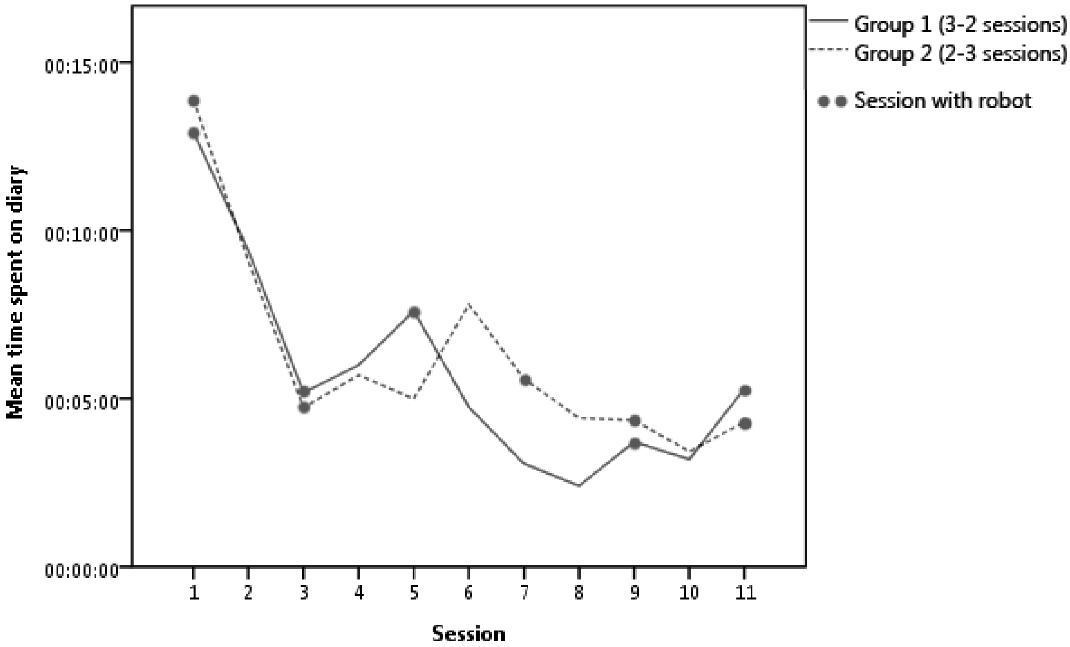

Figure 15 Time spent on diary for all sessions

Again, we need to be careful about arriving at any conclusions based on this data because of the inequality of the data. The only fact the above figure proves is that the time spent on the diary decreases. We can not say the children spent more or less time on the diary when the robot was present.

5.4.2 Active participation

From the experimenter observation logs we learned that the younger children were much more open and talkative. Their answers were longer and their sessions typically took a few minutes longer than those with the older children. They were more likely to ask the robot what he did today, yesterday or last weekend, than the other children were. Older children appeared to be less interested in the robot's life and did not ask him any questions. They usually answered the robot with a simple "yes" or "no". An example of an interested child (aged 9):

> *Child: "Did you play soccer today Charlie?"*
>
> *Charlie: "No, I did not play any soccer today, but I'm going to play with some other robots next weekend!"*

Two children appeared to be very eager to get all their values correct, and so they would log on multiple times to supplement their values. The other children did not spend any more time than absolutely necessary on the diary.

5.4.3 Attention

The children appeared to be very patient when they had to wait a little while for Charlie to answer. This was apparent in the way that the children remained still and focused even when the robot did not do anything for a while. Overall the children were focused. They did not allow themselves to be distracted by background noises or spouses and focused solely on the diary and to a slightly lesser extent on the robot.

The experimenter noticed the children became faster at filling in their values each session (see also Figure 15), and it was increasingly difficult to keep up with them and make the robot respond at the appropriate times. The explanation of the different diary sections in the first session was clear enough so that every child understood it without any apparent problems. They rarely required any explanation in any of the following sessions. The only section they continued to struggle with was the button on the bottom of the diary which they had to click in order to be able to fill out their daily activities. Half of the children tried to click and type in the area directly.

5.5 Bonding

Bonding between the child and the robot is measured by having the children rate the robot after each interaction session, as well as having them answer a post-condition questionnaire about their feelings towards the robot. We also made use of the experimenter observation logs to say something about the subjective level of experience sharing.

5.5.1 Robot ratings

As we mentioned before, after each interaction session, the children answered a short questionnaire about the robot and the diary. Figure 16 displays how the children rated the robot over time, including the 95% confidence interval of the ratings. A rating of 1 in this figure means the child thought the robot was absolutely horrible and a rating of 5 means the child thought it was amazing. The robot received an average rating of 4.2. Just like the diary ratings, we noticed a decrease in the ratings halfway through the experiment (from 4.33 to 3.20). After the third session the ratings increased again to their initial values.

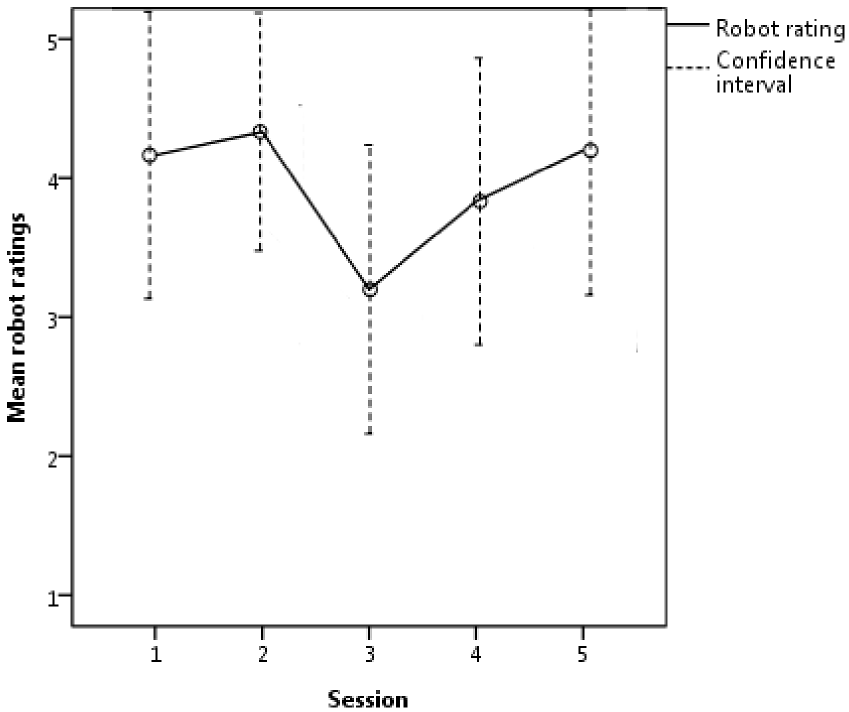

Figure 16 Average ratings given by the children for the robot and 95% confidence interval of ratings.

5.5.2 Child-robot relationship

In the post-condition questionnaire the children were asked to agree or disagree with a number of statements on a scale of 1 to 5, where 1 meant 'completely disagree' and 5 meant 'completely agree'. Table 18 summarizes the results from the post-condition questionnaire.

Table 18 Post-condition questionnaire ratings

Statement	N	Min	Max	Mean	SD
I could understand Charlie well.	6	3	5	3.83	0.75
Charlie has feelings.	6	3	4	3.67	0.52
Charlie understands me.	6	3	5	3.83	0.75
Charlie was trustworthy.	6	4	5	4.50	0.55
Charlie behaves human-like.	6	4	4	4.00	0.00
Keeping the diary was easy.	6	3	5	4.17	0.75
It was difficult to focus when I was keeping my diary with Charlie.	6	1	4	2.33	1.37
Charlie supported me well in filling out my diary.	6	4	5	4.33	0.52

The robot received high ratings on all questions. Some children reported that it was difficult to focus on their diary with Charlie, while others said they had no problems focusing.

When asked what the gender of the robot was, three of the children said that Charlie was male and three said they were not sure what gender Charlie was. Five of the children saw Charlie as a friend. One child said Charlie was more like a peer, and another said that it was a device/robot to him (but also a friend).

Four out of six children reported no negative aspects of Charlie. The other two reported it was sometimes difficult to understand what he was saying. Positive about Charlie was that he was kind and happy, and that he talked a lot and explained things when the child had difficulties with the diary. The children liked the fact that he asked them questions about the things they did that day, as well as share with them his own daily activities.

5.5.3 Interaction with the robot

From the observation logs we gathered qualitative data about the way the children interacted with the robot. Most of these observations are inferences made by the experimenter during or after an interaction session.

The children often smiled or laughed at things the robot said, and waved back to the robot when it greeted them. They were very friendly towards it. The most positive reactions came from the robot's responses to the emotion ratings and daily activities. When the robot immediately said something about a rating or an activity, the child seemed to think that it really understood him/her. They often laughed at Charlie's responses. An example:

> *Child: "I'm going for a swim with my cousin this weekend."*
>
> *Charlie: "Oh that sounds like a lot of fun! I've never gone swimming before."*
>
> *Child: "Hahahaha!"*

The level of detail in the questions some of the children asked was high, regardless of their age. When Charlie said that he played soccer with friends, they would ask him about the final score; if he scored any goals himself; who was the goal keeper (and because Charlie answered she was called Lola, they would ask him if she was his girlfriend). One child even asked about Charlie's birthday, and when he said that was February 2nd, she wished him a happy birthday in advance.

5.6 Miscellaneous results

Any observations that were made during the experiment that did not fit in any of the above categories are mentioned here.

5.6.1 Parental supervision

The parents of the participants were not asked to supervise their children as they filled in their diaries, yet some parents chose to do so anyway. In the beginning of the study, in four out of six cases there was a parent present that sat out of sight to help their child. However by the third session only two parents were still helping out (these were the parents of the youngest children, both 9 years of age). These parents stayed for the rest of the sessions. Figure 17 shows the parent involvement over time.

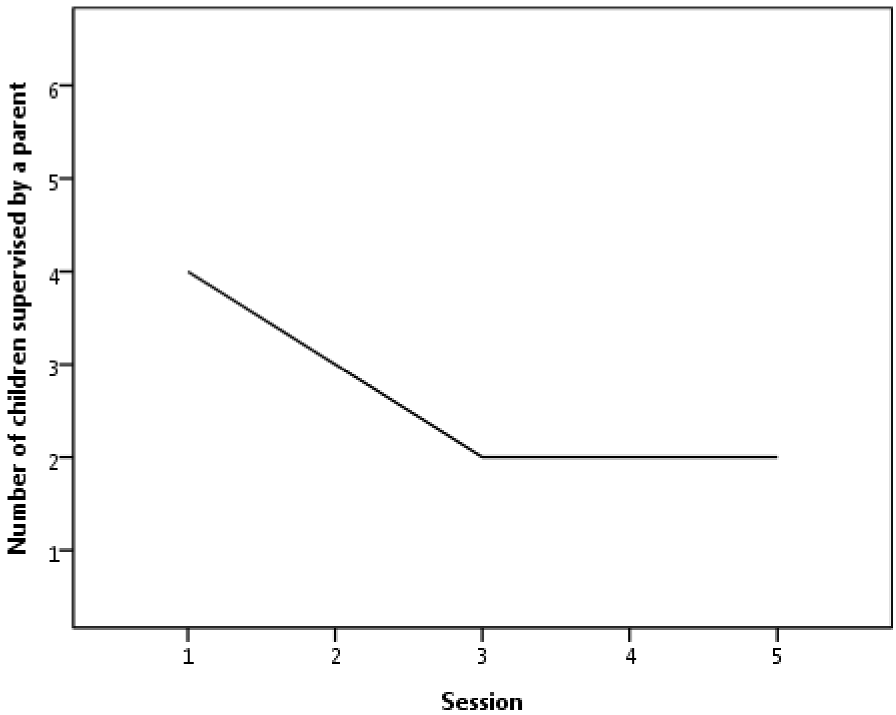

Figure 17 Parental supervision during the robot sessions over time

5.6.2 Connection issues

The internet connection was extremely slow in one case (P2), which caused the robot to be unable to sufficiently respond to any given situation in a timely matter. The delay in sound transmission was between 10 to 20 seconds. In the case of P6 the internet connection was also somewhat slow (delay of 5 to 15 seconds).

Overall the children seemed to understand what the robot was saying most of the time, but he did have to repeat himself occasionally when the sound transmission faltered.

5.6.3 Punctuality

Some children (especially P4) repeatedly forgot their appointments with Charlie. This posed somewhat of a problem for our study. We could have decided to simply cancel the session and hope the child would show up for his/her next appointment, but that would mean losing out on a chance to gather valuable data about the interaction between the child and the robot. In the end we decided the latter was more important to us given the fact that this study was intended as a proof of concept. The experimenter called the children that were late by phone and made sure they showed up on time before the session with the next participant started.

6 Discussion

To investigate how a robot can contribute to the activity of keeping a web-based diary together with diabetic children, we performed a pilot experiment in a real-world setting. So far, ALIZ-E experiments have mostly been performed in controlled laboratory settings or in hospitals. But keeping a diary is an activity that is usually done from home, so we felt that it was important to take the experiment out of the lab and into the real world. Since the robot was already being used in this project, we built our experiment around it. We developed a comprehensive robot dialogue model that enabled the robot to give meaningful advice and engage in personal interactions with the children. The idea was to script most (if not all) of the robot's behavior because the ultimate goal of the ALIZ-E project is an integrated system which does not need a human mediator. A within-subjects experimental design was used in which there were two conditions: keeping a digital diary with the help and support of social robot Charlie; and keeping a digital diary without any such support. The choice to use a within-subjects design instead of a between-subjects or stepped wedge design, was mostly a practical one. First of all we had trouble finding enough children willing to participate in the experiment. Second, we soon realized that there was only a limited time window between the children coming home from school, and the TNO facility, from where the experiment was executed, would close down. Given these time constraints it was not possible to have more than three (or at most four) sessions with the robot on the same day. The influence of using a robot to support the children was tested on three variables: adherence, engagement and bonding. Adherence is the main indicator that a child is performing well in the activity of keeping a diary. The more data is added to the diary, the higher adherence is. From the literature we inferred that among many other factors, the child's engagement in the activity and the child's bonding with the robot can influence diary adherence. There are of course many more factors we could have considered, but since a study like this had never been performed before, we felt these two mediating factors were a good starting point. In total, six children participated in the experiment. They each kept a diary for 11 days, of which 5 days were with the robot, and 6 days without the robot. Having multiple interaction moments makes it possible to track changes over time, and to counter the novelty effect of new technology such as robots. The children each received a laptop equipped with a webcam, microphone and screen-sharing software that allowed them to communicate with Charlie as they kept their diaries. It was not feasible to have the robot visit each of the children to help them keep their diaries, so a remote setup like this was a good solution to that problem. The children used a diary that was modified in cooperation with Mijn Zorgpagina. The modified diary included a new section to keep track of emotional feelings and daily activities. This was an important addition because we know that young diabetics frequently have trouble coping with their condition. This diary would be a way for them to express these emotions. The children answered seven questionnaires in total: one before the experiment, one after each session with Charlie (five in total), and one questionnaire after the experiment. The questionnaire data, along with observations made by the experimenter, and the log data of the diary, were used to answer the three sub questions about diary adherence, engagement and bonding. In the next sub sections we go over the results of each of these measures, pointing out any flaws in our measurements that are relevant to the interpretation of the results.

6.1 Critical discussion of results

6.1.1 Adherence

We found that children left significantly less diary entries uncompleted when they were working with the robot than when they were not. This finding is not surprising considering the fact that the sessions with the robot were mandatory. It was expected of the child to fill in the diary when he/she was communicating with the robot. A critical note with regard to the diary completion is that we called the children who forgot their appointments with Charlie. We were afraid that if we did not remind them, some of them would end up forgetting all about the experiment and we would lose out on valuable data. Considering the small sample size we had, we felt it was more important to have as many interaction sessions as possible to learn what we could about how the robot influenced diary adherence. We found that the children consistently filled in more information in their daily activities logs (the bottom part of the diary) when they were keeping their diary with the robot, than when they were keeping it by themselves. This one of the most important findings of the experiment. Regardless of whether or not the children were reminded of their appointments, when they *did* interact with the robot, they filled in much more information. Although our sample size was small, this finding held true for all participants. We did however see the emergence of three different types of participants: those who always fill in large quantities of data, those who filled in 50% or less without the robot, and those who did not fill in anything at all. We are not sure as to what causes this difference. It could be coincidence, but it could also be due to personality traits of the participants. We saw that the children were relatively positive about the diary, but that there was a decrease in the ratings halfway through the experiment. We found the same result in the ratings for the robot. We are unsure as to why exactly this is. It could just be due to the large variation in the answers because of the small sample size; a larger sample could yield different results. But another possible explanation could be that the novelty of the robot and the diary has worn off after the second session. This would be consistent with literature on the novelty effect in long-term child-robot interaction (Oh & Kim, 2010). But this does not explain why the ratings increase again to roughly their initial values by the end of the fifth session. We suspect that the following increase might have something to do with the bond that is formed between the robot and the child, which we will come back to later.

6.1.2 Engagement

We measured engagement by investigating the time spent on the diary, and the level of active participation and attention during the interaction sessions. Due to an unforeseen gap in the log information provided by Mijn Zorgpagina, we were unable to determine whether the children spent more time on their diaries with the robot or without it. But we suspect the difference between the conditions would have been small and probably not significant. From the log data we gathered that the time taken to fill in the diary dramatically decreased after the first two sessions. This is not surprising because in the first session the children had to listen to the robot explaining every diary section, while in subsequent interactions this explanation was optionally accessible (though rarely asked for). The second session was one in which the children were filling in their diaries by themselves for the first time. It is to be expected that this session took a little bit longer as well because they had to remember what the robot had told them previously. Towards the end of the experiment, a diary session typically lasted under five minutes, which is a rather large decrease from the initial 11 minutes it took them on average in the first session. Initially we had planned to record all interaction sessions to carefully note any changes in active participation and attention. However, due to a technical problem the screen sharing software crashed when the recording software was started. We came to rely on the experimenter observations for data regarding the children's engagement. It is important to note that the experimenter was quite busy during the experiment operating the robot, so there was limited time to observe. Also, the observations can be colored by the experimenter's own interpretation and are not always as objective as we would like. We do believe however that we saw a strong difference in active participation between the younger children, who were much more open and talkative, and the older children, who preferred simple "yes" or "no" answers. We suspect that perhaps the background story for Charlie was not convincing or appealing enough for the older participants in this study. This would be in line with the commentary we received from an older child during the pilot study we performed prior to the experiment. Overall, the experimenter had the impression that the children paid close attention to the robot and the diary. They did not allow themselves to be distracted by background noises, siblings or parents. While some parents chose to supervise their child during the sessions, they did not appear to be a distracting factor. We did however see some mixed results in the answers on the question whether it was difficult to focus when they were keeping a diary with Charlie (in the post-condition questionnaire). But this might also be to the slow internet connections of some children. Occasionally there would be very large delays in the sound transmission, which made it difficult to understand what Charlie was saying.

6.1.3 Bonding

We believe the forming of a bond between a child and the robot could positively influence diary adherence, so we measured changes over time in their relationship. Overall, the robot was received very well by the children. Most of the time, they enjoyed interacting with Charlie. We saw the same gap in the ratings of the interaction sessions for the robot as we did with the diary. As we mentioned before, this could be due to the novelty effect of the robot wearing off after the second session, but we cannot confirm this theory. To determine how the children viewed the robot after having kept a diary with it for two weeks, we asked the children to agree or disagree with a number of statements in a post-condition questionnaire. When interpreting these results, it is important to realize that sometimes part of the dialogue was typed by the experimenter directly and converted to speech by the robot when there was no suitable answer in the dialogue model. As a consequence, sometimes the children were in some way talking to the experimenter rather than the robot. From the results we gathered that the children believed Charlie had feelings and behaved human-like. They also felt that it was able to understand them, and that he was trustworthy. The children all said that Charlie supported them well in filling out their diaries. Five out of six children indicated that they saw Charlie as a friend rather than a peer, doctor or device. The children indicated they liked the fact that Charlie talked with them about their days and helped them keep the diary. They also felt that he was kind and happy. The experimenter observation logs further confirm the positive attitude towards the robot. The children often smiled and laughed at the things the robot said (in a positive way). They asked many detailed questions about Charlie's personal life. We think this is a promising result because we learned that a strong social support network is important for coping with diabetes. Charlie has the potential to become part of that support network as a supportive peer or friend.

6.2 Implications for theory and practice

6.2.1 Social robotics

Our results show that having a robot disclose personal information about itself makes the (intrinsically dull) task of keeping a diary a lot more enjoyable. It would be interesting to see if this holds true for other social robots and tasks as well. For example, what if a cleaning robot were to talk about how much it enjoys the smell of a nice clean house? Would users be more inclined to like the robot if it shared its personal feelings?

We also saw that the robot was believed to behave human-like and that it supposedly had feelings. This was to be expected because children are known to frequently assign human characteristics to non-living objects. However, we need to realize that some of the phrases the robot uttered were in fact typed by the experimenter. We cannot be sure to what extent these feelings towards the robot would have been affected if this had not been the case.

6.2.2 ALIZ-E

This study was one of the first times that an ALIZ-E experiment was taken out of the laboratory, school and hospital settings, and was placed in a more natural setting: the child's home. Diabetes management is not something that is done in just one particular place at one particular time; it is an ongoing process that can be triggered anytime, anywhere. By having the child keep a diary from home with help of the robot, we have shown that there is potential for this type of support in the real world, not just the lab.

The dialogue model we developed specifically for the diary activity can be re-used in future experiments. The task-related part of the dialogue (solely focused on guiding the child through the process of filling in the diary) performed really well in the experiment. Thanks to the robot's explanations, the children did not experience any serious problems in keeping the diary. The robot was able to provide explanations where necessary, and answer most of the questions the children had. However, the small talk (personal dialogue) part of the model does still need some work. The pre-programmed sentences were often insufficient to appropriately respond to a child's stories or personal questions. The experimenter had to manually type responses that were then converted to speech by the robot to remedy this issue. This is of course detrimental to the integrated autonomous system that ALIZ-E envisions.

A promising result is the fact that the children thought the robot remained interesting even after they had completed five sessions with it. The fact that they describe the robot as being their friend shows that there is truly some potential in using robots such as Charlie to become a buddy for diabetic children. They enjoy talking with him, and he makes keeping the diary a little bit more interesting. Future research within ALIZ-E could attempt to combine several of the activities that have been developed so far (imitation, dance, quiz and diary) to provide a more wholesome experience for the diabetic children.

6.2.3 Self-management of children with diabetes

On first glance, using a social robot to support children's self-management appeared to be successful. They enjoyed keeping a diary together with Charlie and liked to be able to talk with him about their daily experiences. The robot could become part of their social support network as a somewhat "neutral" friend to interact with. But unfortunately, the robot does not appear to have a lasting effect on a child's willingness to keep a diary. Of the six children that participated in this study, only one of them asked if he could continue using the diary (albeit without Charlie). For most children, as soon as Charlie was out of the picture, they quickly fell back into their old habits. A onetime intervention does not appear to have the desired lasting effect.

An explanation for this could be that for these children, the intervention came too soon. Prochaska and Norcross (2001) conceptualized behavior change as a process that unfolds over time and involves progression through a series of six stages (although the sixth is often omitted): precontemplation, contemplation, preparation, action, maintenance and termination. It is important to tailor the therapy to the stage of change the user is in. For example: if the child has not even considered keeping a diary, it will not have any effect to provide this child with information on how to accomplish that. Instead, this child should be offered information on why such a behavior change is necessary. Most of the children appeared to be unaware of why keeping a diary would be beneficial to their well-being. They are in the *precontemplation stage* where they have no intention of changing their behavior in the near future (within the next 6 months). Most of them will be unaware or under-aware of their problems. Before looking into a permanent type of support for keeping a diary (for example using a digital coach that is always available instead of a robot), we need to address this issue. The children need to be made more aware that a problem exists in order to move to the contemplation and preparation stages and eventually undertake the necessary action.

7 Conclusion

Diabetes self-management is a complex process, especially for young children. Studies have shown that they often have trouble coping with their condition in a healthy manner. According to diabetes doctors and nurses, it would be beneficial for the children to keep a diary in which they note their physical as well as their emotional well-being. In practice however, children often do not keep a diary at all. In order to motivate children, we have investigated how a social robot can play a role in keeping a diary. We developed a dialogue model for the robot that was used to support the children in the execution of the task, and to discuss their emotional state and daily activities with them. The robot was also capable of sharing information about its own personal life, inviting the child to do the same in return. Six children each kept an online diary for two weeks from home, communicating with the robot every other day using a webcam and screen-sharing software. The main research question we formulated was:

> *How can a robot contribute to the activity of keeping a web-based diary together with diabetic children?*

De foremost way of determining whether or not adding the robot to the activity was a successful intervention, is by looking at the amount of data the children enter in their diaries (diary adherence). We wanted to know in what way the robot impacts diary adherence, which led us to the first sub question:

> R1: *How does communicating with the robot while filling in the diary help improve children's diary adherence?*

Engagement is the most contributing factor in learning and also supports self-management. An engaged child will typically spend more time on a task and take a more active role in the interaction. We were curious to see what would happen to a child's engagement when they were keeping a diary while interacting with the robot:

> R2: *How engaged are the children with their diaries when they interact with a robot?*

The children in this study interacted with the robot over the course of two weeks. During this time they both shared personal information about themselves with each other. We wanted to know if there formed a bond between the two over the course of this experiment, thus leading us to the third sub question:

> R3: *How does the relationship between the child and the robot evolve over time?*

In the next sections we will address these questions separately to come to our final conclusion.

7.1 Answers to research questions

7.1.1 The effect of communicating with a robot on diary adherence

Self-monitoring of blood glucose plays a critical role in the effective management of insulin-dependent diabetes mellitus. However, keeping a record of these values was proven to be problematic for many patients. From the literature on monitoring of diabetes, we inferred that keeping a digital diary instead of a paper diary would yield much better diary adherence results. We also learned that peer support leads to an improved quality of life, as well as better metabolic control. We wanted to know if and how the robot could fulfill the role of a supportive peer and help children improve their diary adherence by communicating with them while they filled in their diaries (R1).

In the focus group we found that children typically did not keep a diary, or that their parents were mostly responsible for it. We found out that the same was true for the participants in our experiment. Most children did not keep a diary, and when they did, their parents often took responsibility for it. This suggests that low diary adherence is a common problem among all diabetic children. We found some evidence that diary adherence improved when the robot was present. When children were interacting with the robot, they wrote significantly more in their daily activity logs and left far fewer diary entries uncompleted. Not all children completed their diaries on time. Some children would go back to the diary at a later point in time and complete the missing entries; however, this was true for only some of them. A few children also supplemented their diaries with extra information when it became available. But there was no significant difference between the conditions in the supplementary actions undertaken. The diary was rated moderately positive throughout the sessions.

The robot appears to be a big stick for the children to complete their diaries. The fact that someone else is watching them could make them feel more obligated to do what is expected of them. Discussing the contents of the diary with the robot also serves as an incentive to reflect on the data entered. But we do not think the watchful eye of the robot was the only reason we found a difference in diary adherence. As we will see in the following sub sections, the children greatly enjoyed being able to talk with the robot about their diaries. Joy is also a very strong motivator to perform a certain task.

7.1.2 Engagement of children in keeping a diary with the robot

Measuring engagement of the children is an important part of determining the contribution of the robot to the activity of keeping a diary. An engaged child will spend more time on the task and take an active role in the interaction. We wanted to investigate how engaged the children were with their diaries when they interacted with a robot (R2).

Due to a gap in the log data, we were unable to compare the total time spent on the diary between conditions as a measure of engagement. Although we did see that the time spent on the diary decreased over time and stabilized at around five minutes, we cannot say the children were *more* engaged when they were working with the robot solely based on this data. We were also unable to record the interaction sessions with the robot to objectively analyze the level of engagement during the sessions. Instead, we came to rely on the experimenter observation logs for this information. We found that younger children (9-10 years of age) were more open and talkative than the older children (11-12 years). They showed more initiative in asking Charlie questions and telling him stories. We think this difference is due to the story of Charlie being trained to become a care robot is more suited to a younger audience. Overall, we saw high levels of engagement throughout the interaction sessions. The children were rarely distracted by their surroundings. Their main focus was the diary, the robot came second. Usually their attention shifted towards the robot when it spoke or moved, and then back to the robot. A few children said that the robot distracted them from their diary; others felt the robot was not distracting at all.

7.1.3 The relationship between the child and the robot

The support of friends or peers is important in coping with childhood and adolescent diabetes. This support network usually consists of doctors, teachers, parents and friends, and we believe that Charlie could fulfill a role as well. The task of keeping a diary is not inherently fun or interesting to a diabetic child, but communicating with

Charlie could make the activity more interesting. The children interacted with the robot over the course of two weeks, and we were curious to see how this relationship between them developed over time (R3).

Initially the robot was regarded very positively, but after a few sessions the child started to lose interest. Then by the end of the experiment, the ratings given to the robot rose again to their initial values. We believe the reason for this lies in the forming of a bond between the child and the robot. Five out of six children said to consider the robot a friend by the end of the experiment. We also found that they readily attributed human characteristics to the robot. They believed it had feelings, and that it understood them. They also thought it to be trustworthy, and despite its limited physical and cognitive abilities, they thought it behaved human-like. When asked what the children liked about the robot, they said that he was kind and happy, and that he was able to help them out when they were experiencing difficulties with the diary. Most of all, they liked that the robot shared information with them about its own daily activities, and that it asked them about how their day was. As the sessions progressed, the experimenter noticed the children gradually stared sharing more personal information with the robot. This is in line with the results found by Collins and Miller (1994) about the relationship between likeability and self-disclosure. The child likes the robot because it discloses personal information about itself. As a result of liking the robot, the child will disclose information to the robot in return.

7.1.4 General conclusion

A social robot can enhance the pleasure of the activity, and therefore the motivation of the child. Especially once the robot and the child really get to know each other, the child starts to consider the robot as a friend and he/she really opens up to it. When we take into account that the diary adherence prior to this study was almost non-existent, this is a considerable improvement. We think that a robot could help the children overcome the initial hurdles of taking charge of their own diabetes self-management. Keeping a record of the values and the daily activities allows the child to make meaningful inferences about the relationship between these two. They can learn to recognize when their glucose levels are stable and when they are not. This enables them to take the necessary precautions when they encounter a similar situation in the future. The addition of a robot does not have to be detrimental to the child's feeling of independence, which becomes increasingly important as they reach puberty. In fact we saw that parental supervision of the activity decreased after a few sessions. The parents became more comfortable leaving the children to complete their diaries on their own.

However we need to realize this was only a small-scale study and the results are difficult to generalize for the entire population of diabetic children. There were several issues with the measurements which make it difficult to correctly interpret the results. We also need to be careful in saying the results we observed were solely because of the robot. There is a common phenomenon known as the Hawthorne effect where subjects improve or modify an aspect of their behavior being experimentally measured, simply in response to the fact that they know they are being studied (McCarney et al., 2007), not in response to any particular experimental manipulation. It is possible that the differences we observed between the conditions were because of the Hawthorne effect. For most of the children, this was one of the first times someone was actively paying this much attention to their diaries.

7.2 Future research

Several hospitals have already shown interest in cooperating with TNO to repeat the experiment on a larger scale. In the Discussion we have already pointed out some flaws of this study. In this section we make concrete recommendations for future research.

7.2.1 Diary

In this study we did not add any explicit feedback about the relationship between (glucose) values and the self-reported daily activities and emotions. Although this relationship was implied, the robot never told the child how they were intertwined. It is questionable whether children will be able to figure out this relationship on their own. In the future it would be interesting to add this type of feedback to the conversation. The robot could make inferences about cause and effect, and explain to the young patients that the way they feel is strongly correlated to the way they take care of their bodies when treating their diabetes. It would also be beneficial to look at the graphs of the values together and talk about any noticeable patterns in the data. This would mean however that the robot would need to have more medical knowledge in order to provide medically sound advice, thereby taking the role of doctor more than a buddy. We discussed the ethical issues associated with provided medical advice through a robot in the methodology section. The question remains whether this is a desirable development; do we really need a robot doctor? Or do we just need someone to talk with?

7.2.2 Small talk

We heavily underestimated the level of detail in the conversations between the children and the robot. The way we see it, there are two ways to address this issue. One is to expand the amount of small talk in the dialogue structure, but this raises the question of when it will ever be enough. It is difficult to predict in advance the direction the conversation will take. The other way to address the issue is by keeping the small talk more general, or providing generic responses to the children's questions. This has the disadvantage of making the conversations far less spontaneous and duller. When a child asks a question, it expects a certain answer; and when he/she does not receive that answer, disappointment sets in. In this study we remedied the "small talk issue" by having the experimenter type a quick response in the text to speech interface when there was no suitable answer available in the dialogue tool. Of course this is far from an optimal solution, because ultimately the goal of the ALIZ-E project is to develop an integrated system in which the robot will be able to operate on its own without interference from the experimenter.

7.2.3 Experiment design

We chose to use TeamViewer to share screens and talk over webcam and microphone mostly because it was freely available and not too complicated in use. However, using additional software just to talk seems a little superfluous. In the future it might be worth developing a website/diary that has the screen-sharing option built in. Preferably something that is easy to access or install on a participant's own desktop computer or laptop so that they do not need one that is pre-installed. Optionally, it would also be possible to use a virtual representation of the robot rather than a physical one. Although there are proven advantages to using an embodied robot over a virtual agent, it is not always a viable option. Robots are still incredibly expensive and they break rather easily. A virtual agent would be much more robust, albeit less engaging. We think it is worth repeating the study with a virtual agent to compare the results and see if this prediction holds true. This virtual agent could also be embedded in a mobile application. Smartphones are becoming ever more prevalent and the medium seems suitable for keeping a diary on the go. However, one could question whether the children in this study are old enough to even be using an expensive smartphone. This option might be better suited for the adolescent diabetics.

7.3 Closing scenario

We started this thesis by sketching a scenario of a young child struggling with his/her diabetes. Now, we come back to the scenario to see what has changed:

"You are now 10 years old and starting in high school soon. Effectively managing your diabetes is still difficult sometimes, but you are getting better at it. Your parents still help you but also give you enough freedom to learn to do things by yourself. The doctor recommended you keep track of how you are doing physically and emotionally in an online diary. While initially resisting this added responsibility, you find that keeping the diary is not as cumbersome and boring as you thought it would be. The friendly robot Charlie is always there for you to talk to. It is nice to be able to speak to someone other than your parents or doctors about your diabetes. Charlie helps you fill in your values and chats with you about your day. And when you are interested, he can tell you about his life as well. You consider Charlie to be your friend. Together you have also made some interesting discoveries about your diabetes management which has helped the doctor adjust your treatment plan. Your diabetes will never go away, but Charlie helps making it all a little more bearable."

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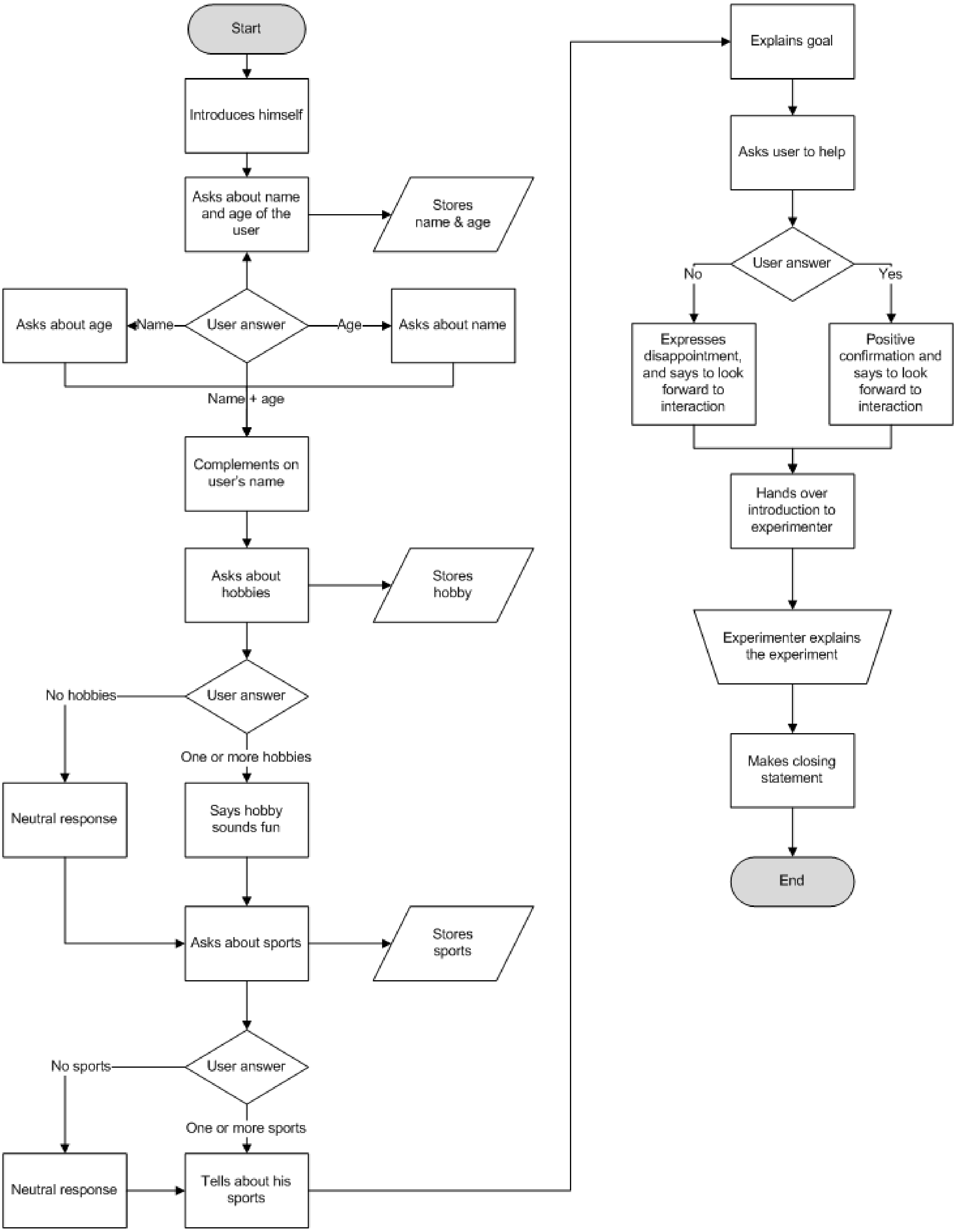
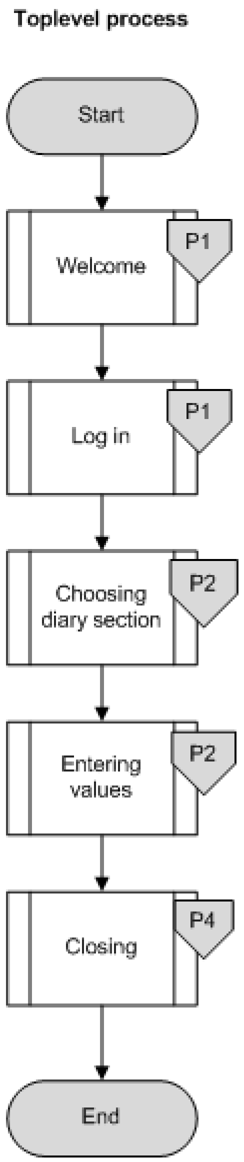
Appendix A: Robot dialogue model

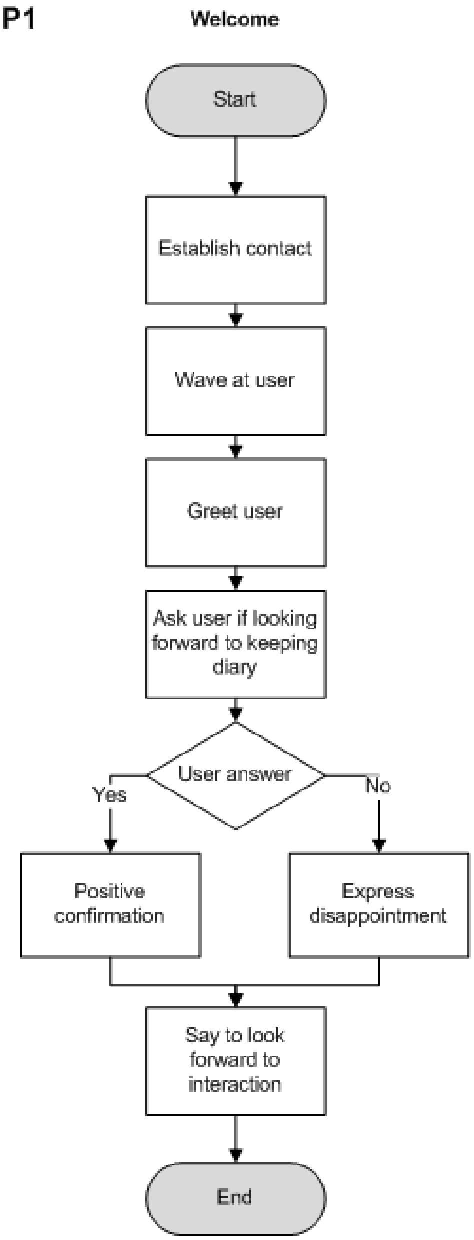
Introduction session

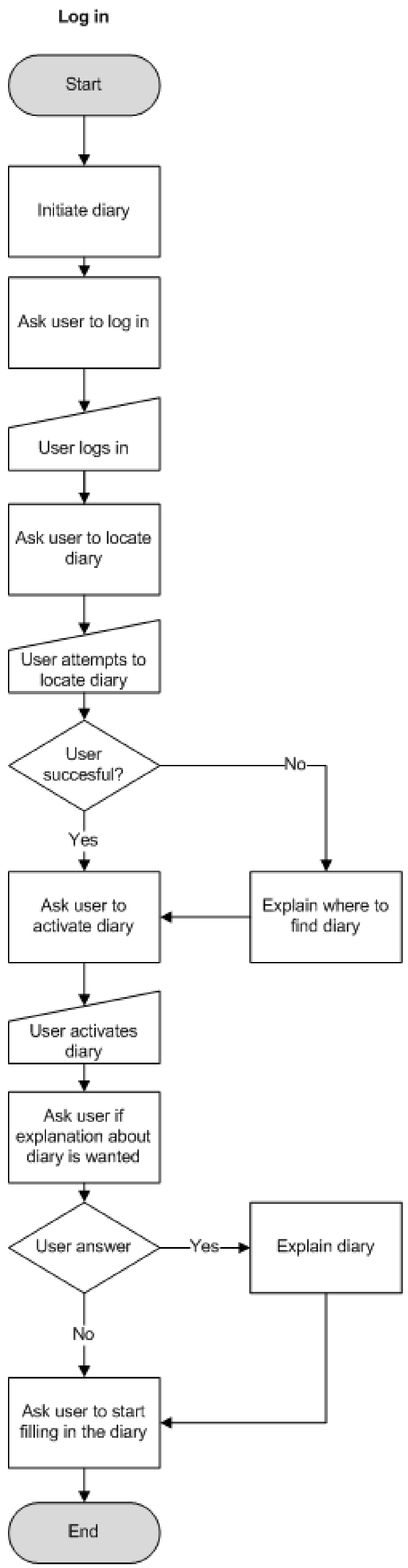


Interaction session

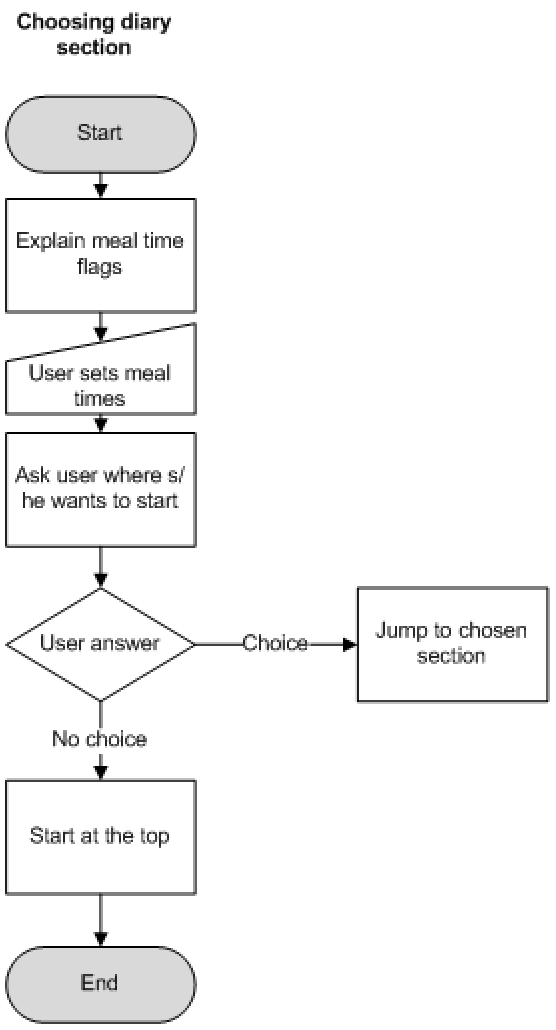


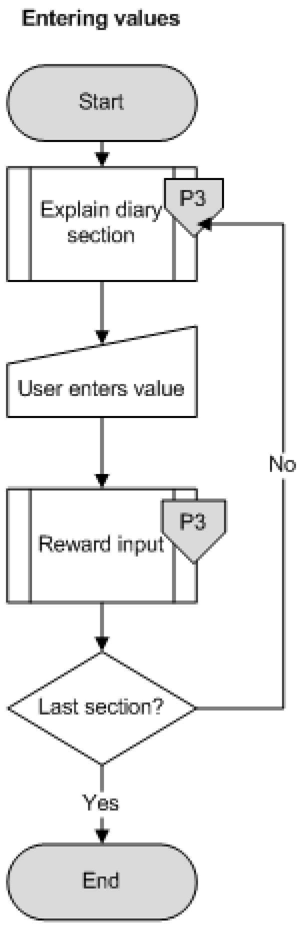
P1


Welcome
Start
Establish contact
Wave at user
Greet user
Ask user if looking forward to keeping diary
User answer
Yes
No
Positive confirmation
Express disappointment
Say to look forward to interaction
End

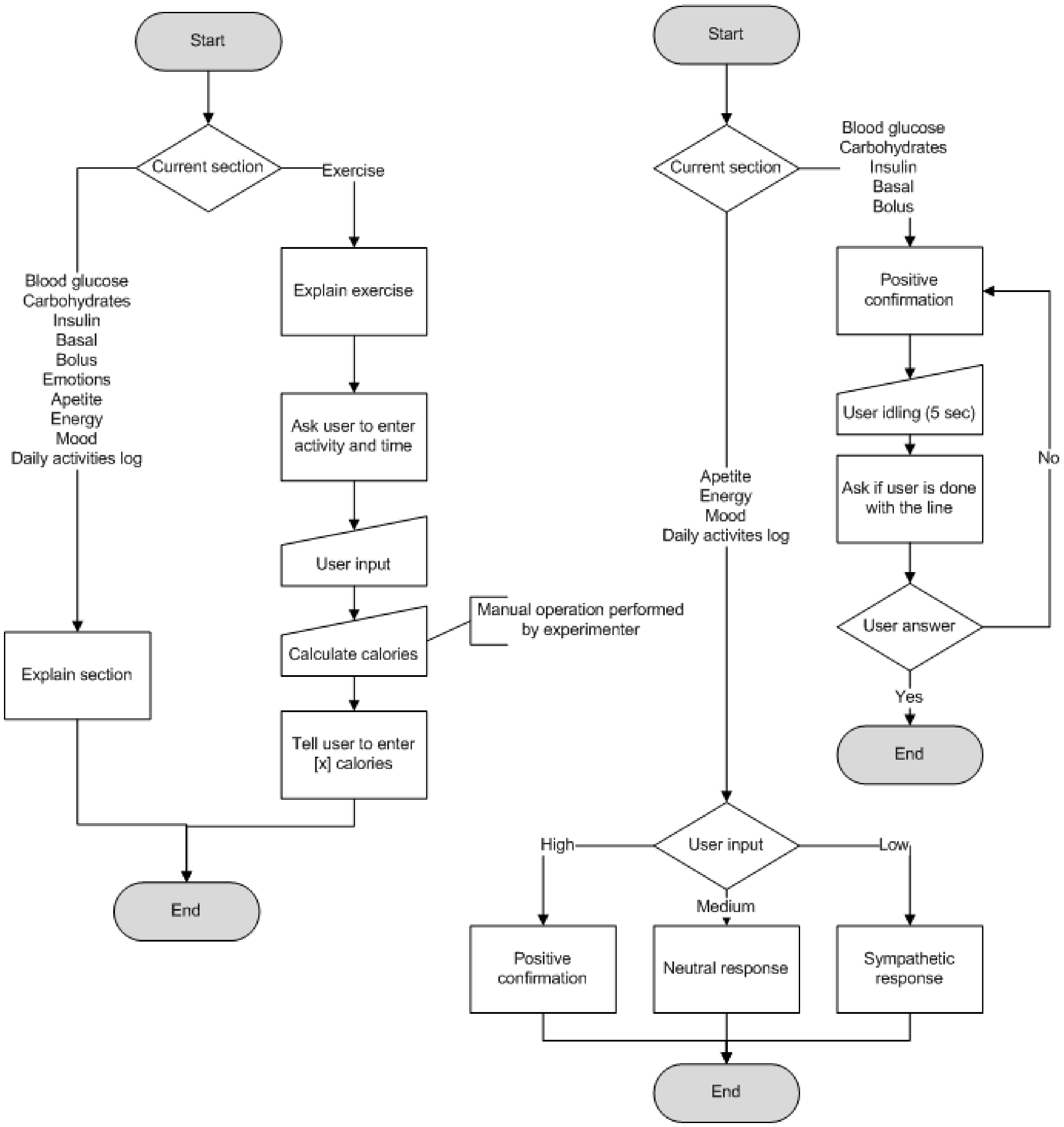

Log in
Start
Initiate diary
Ask user to log in
User logs in
Ask user to locate diary
User attempts to locate diary
User succesful?
No
Yes
Ask user to activate diary
Explain where to find diary
User activates diary
Ask user if explanation about diary is wanted
User answer
Yes
Explain diary
No
Ask user to start filling in the diary
End

P2

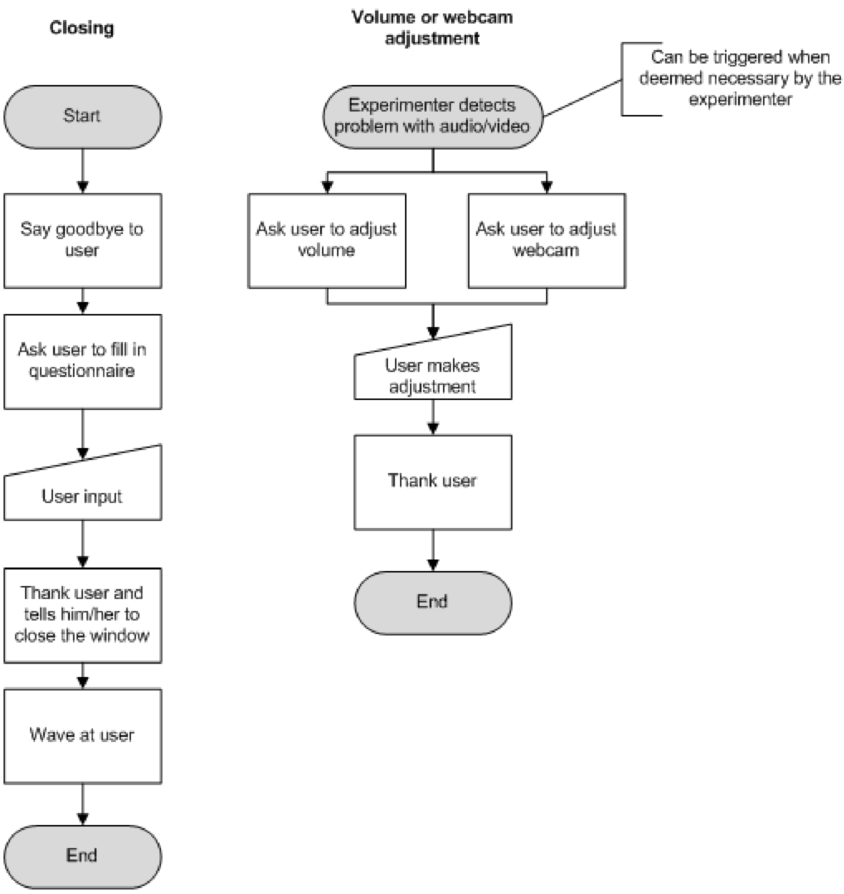

Choosing diary section
Start
Explain meal time flags
User sets meal times
Ask user where s/he wants to start
User answer
Choice
Jump to chosen section
No choice
Start at the top
End

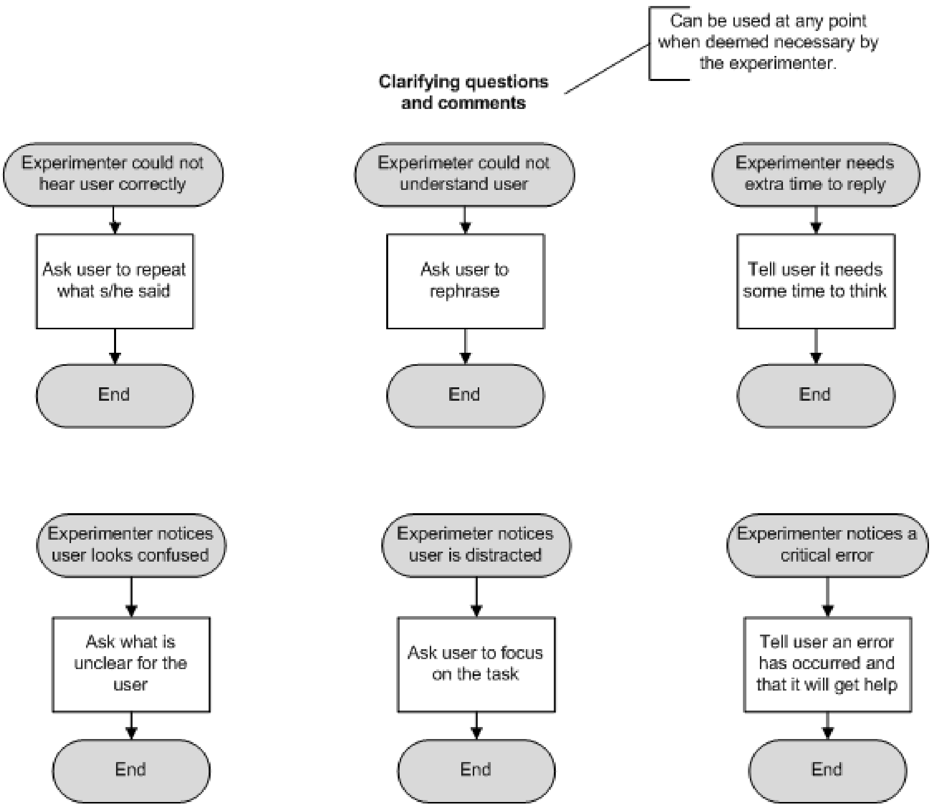

Entering values
Start
Explain diary section
P3
User enters value
Reward input
P3
No
Last section?
Yes
End

P3 **Explain diary section** **Rewarding input**

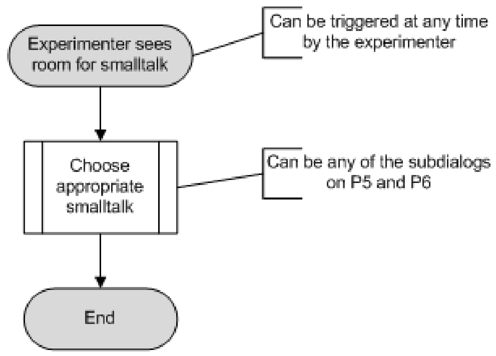


P4

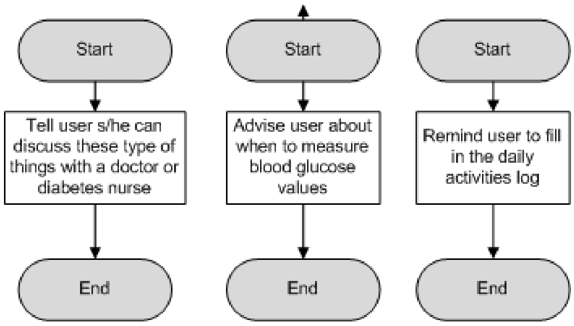

Closing
Start
Say goodbye to user
Ask user to fill in questionnaire
User input
Thank user and tells him/her to close the window
Wave at user
End
Volume or webcam adjustment
Can be triggered when deemed necessary by the experimenter
Experimenter detects problem with audio/video
Ask user to adjust volume
Ask user to adjust webcam
User makes adjustment
Thank user
End


Can be used at any point when deemed necessary by the experimenter.
Clarifying questions and comments
Experimenter could not hear user correctly
Ask user to repeat what s/he said
End
Experimeter could not understand user
Ask user to rephrase
End
Experimenter needs extra time to reply
Tell user it needs some time to think
End
Experimenter notices user looks confused
Ask what is unclear for the user
End
Experimeter notices user is distracted
Ask user to focus on the task
End
Experimenter notices a critical error
Tell user an error has occurred and that it will get help
End

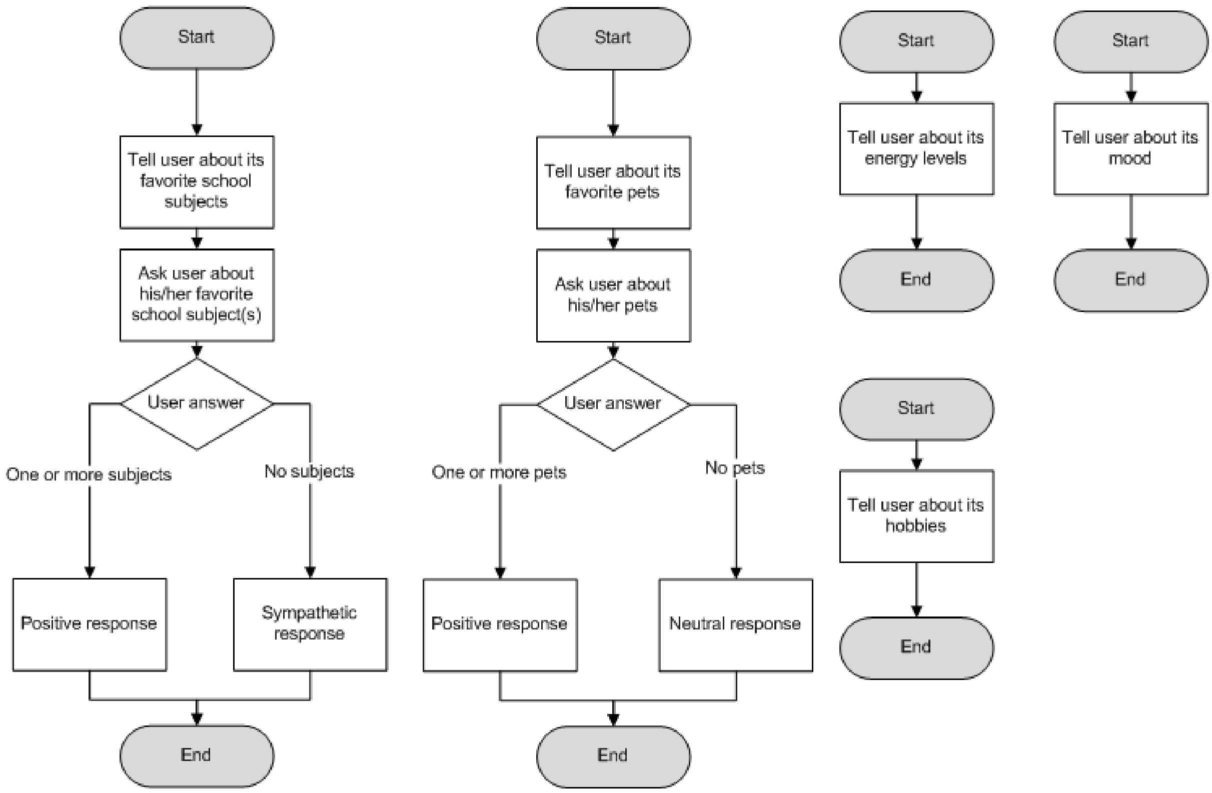
P5 **Smalltalk selection**



Diary-related smalltalk

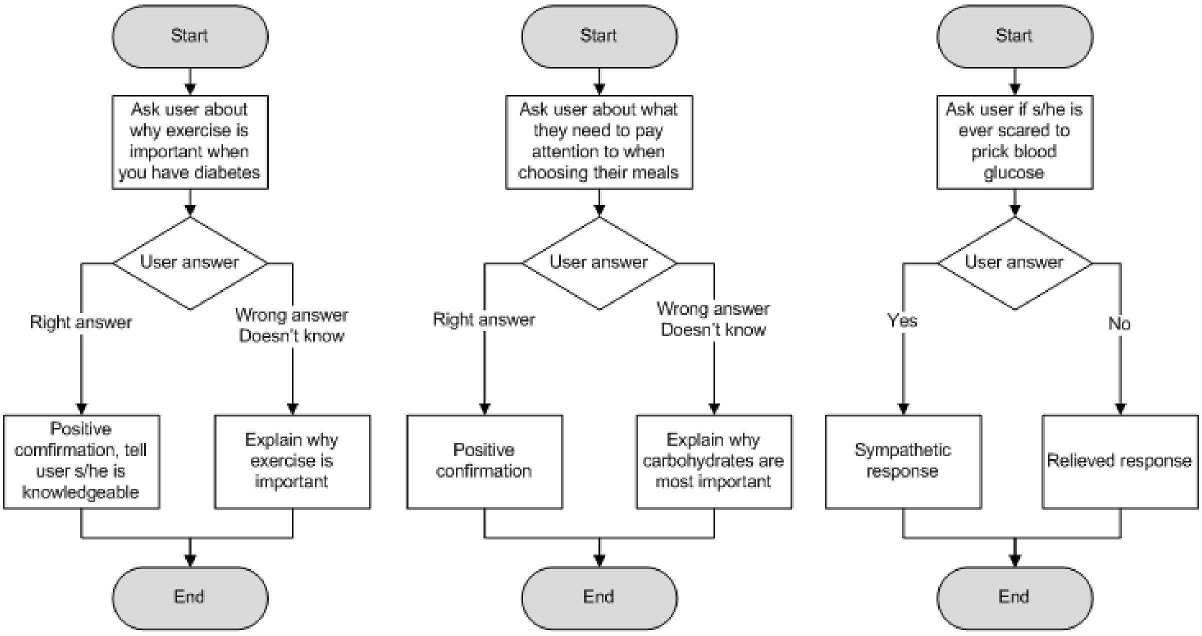


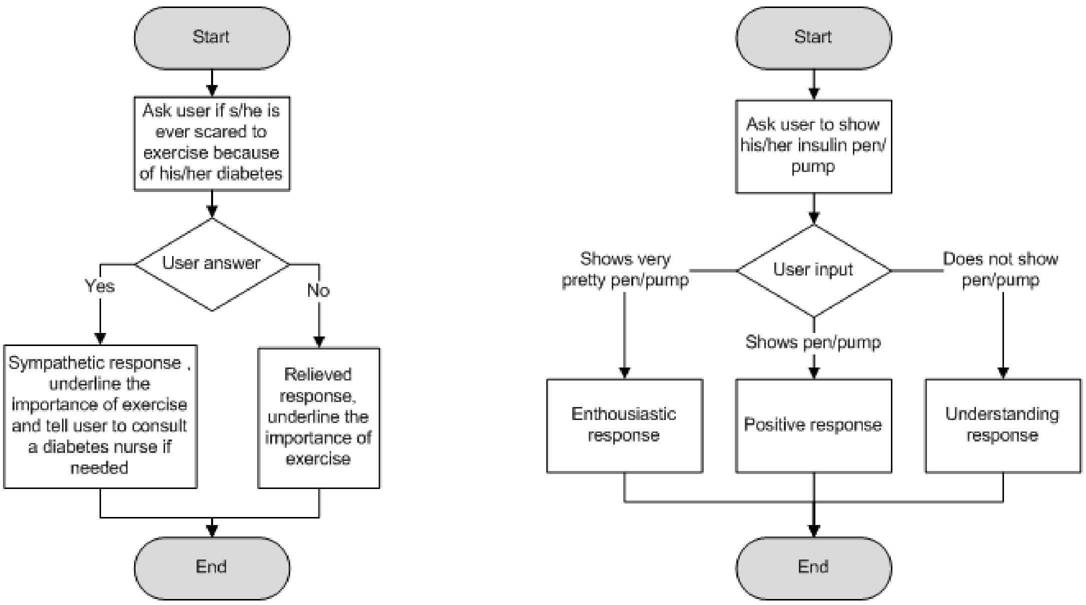
Self-disclosure smalltalk



P6

Diabetes-related smalltalk





Appendix B: Questionnaires

Pre-condition questionnaire

Naam	....
Leeftijd	.... jaar
Ik heb diabetes sinds	.... (jaartal of leeftijd)
Heb je familieleden met diabetes?	....
	....

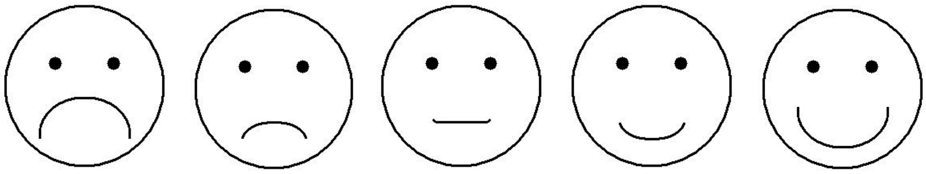
Ik vind nieuwe technologie zoals robots (kleur het rondje)	O heel interessant O beetje interessant O niet zo interessant O helemaal niet interessant
Mijn diabetesdagboekje	O houd ik zelf bij O houd ik samen met mijn ouder(s) bij O houden mijn ouders bij O houden wij helemaal niet bij
Hoe vaak maak je gebruik van je diabetesdagboekje? (bijv. elke dag, drie keer per week)	....

Ik denk dat een online dagboekje ………… is dan een papieren dagboekje (je mag meerdere antwoorden kiezen)	□ Fijner □ Langzamer □ Sneller □ Makkelijker □ Moeilijker □ Leuker □ Vervelender □ Geen verschil
Wat denk je dat de robot allemaal kan of gaat doen?	…………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………
Heb je er zin in om samen met de robot je dagboekje in te vullen?	O Ja O Een beetje O Nee

Interaction session questionnaire

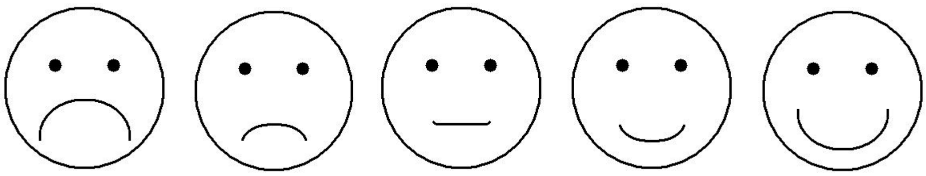
Je hebt net samen met Charlie je dagboekje ingevuld. Wat vond je ervan? Kleur het rondje in bij het antwoord waar jij het mee eens bent. Je mag helemaal eerlijk zijn!

1) Wat vond je van Charlie?



vreselijk	niet zo leuk	leuk	heel leuk	geweldig
O	O	O	O	O

2) Wat vond je van het invullen van je dagboekje?

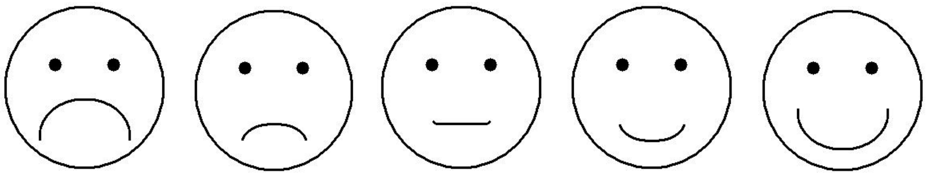


vreselijk	niet zo leuk	leuk	heel leuk	geweldig
O	O	O	O	O

Post-condition questionnaire

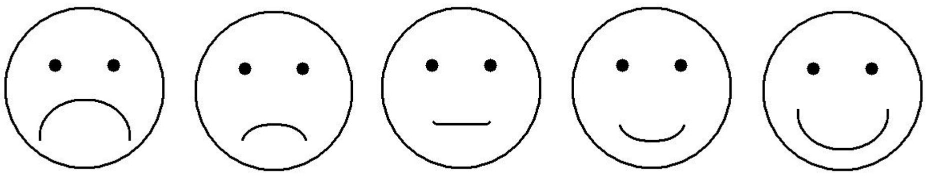
Je hebt twee weken lang samen met Charlie je dagboekje ingevuld. We willen natuurlijk graag weten wat jij daarvan vond! Op deze bladzijden staan vragen over Charlie en je dagboekje. Kleur het rondje in bij het antwoord waar jij het mee eens bent. Je mag helemaal eerlijk zijn!

1) Wat vind je van Charlie (na deze twee weken)?



vreselijk	niet zo leuk	leuk	heel leuk	geweldig
O	O	O	O	O

2) Wat vind je van het invullen van je dagboekje (na deze twee weken)?



vreselijk	niet zo leuk	leuk	heel leuk	geweldig
O	O	O	O	O

3) Denk je dat Charlie een jongen of een meisje is?

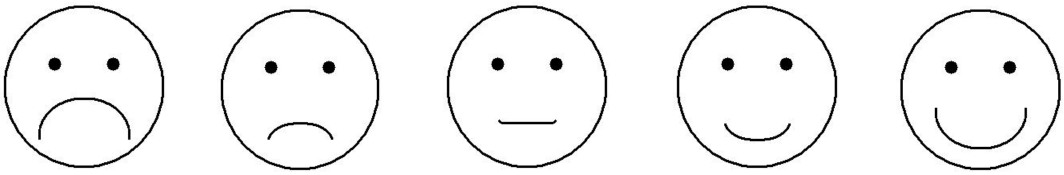
O Jongen

O Meisje

O Geen van beide

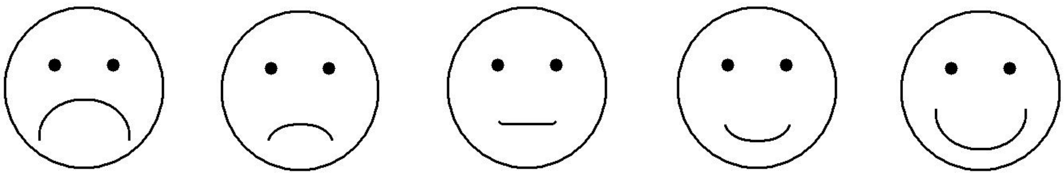
O Weet ik niet

4) Ik kon Charlie goed verstaan.



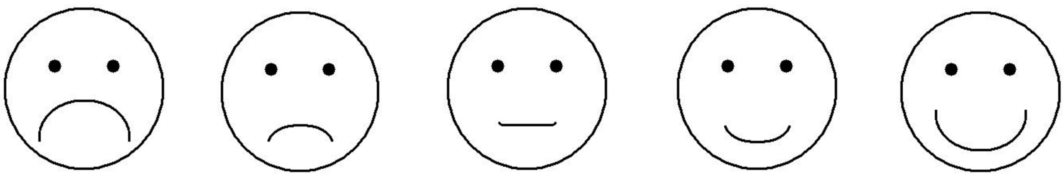
helemaal oneens	oneens	neutraal	eens	helemaal eens
O	O	O	O	O

5) Charlie heeft gevoelens.



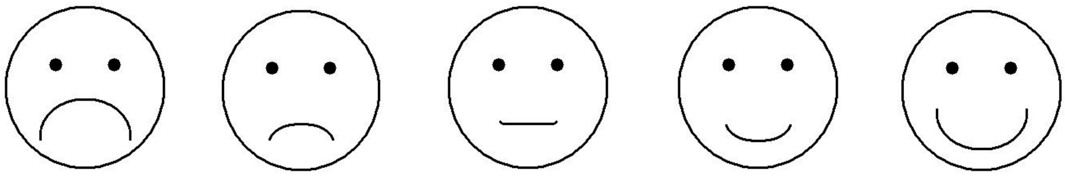
helemaal oneens	oneens	neutraal	eens	helemaal eens
O	O	O	O	O

6) Charlie begrijpt mij.



helemaal oneens	oneens	neutraal	eens	helemaal eens
O	O	O	O	O

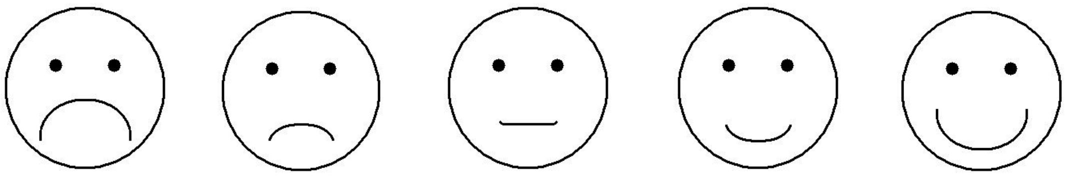
7) Ik vertrouw Charlie.



helemaal oneens   oneens   neutraal   eens   helemaal eens

O   O   O   O   O

8) Charlie gedraagt zich als een mens.



helemaal oneens   oneens   neutraal   eens   helemaal eens

O   O   O   O   O

9) Charlie was voor mij een (je mag hier meerdere antwoorden kiezen)

□ Vriend/vriendin

□ Leeftijdsgenootje

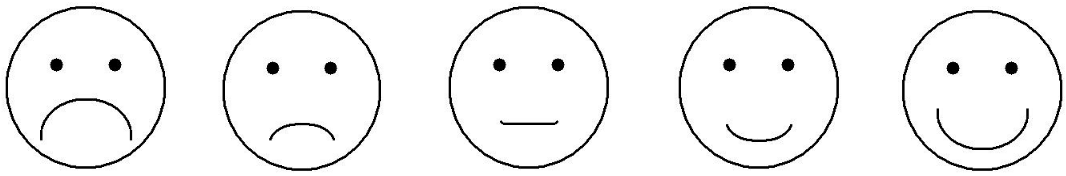
□ Verpleger/verpleegster

□ Apparaat

□ Ouder

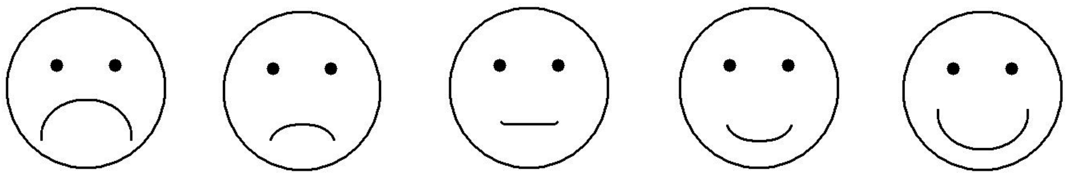
□ Iets anders, namelijk …………………………………………………………………

10) Ik vond het invullen van het dagboek makkelijk.



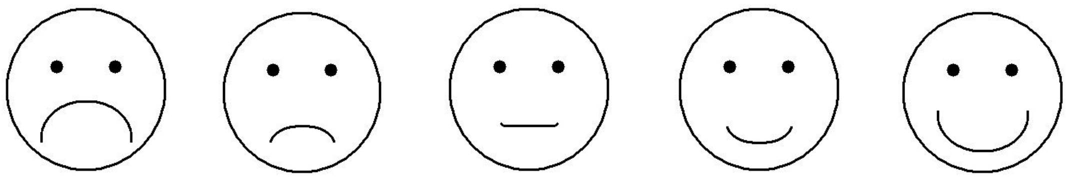
helemaal oneens	oneens	neutraal	eens	helemaal eens
O	O	O	O	O

11) Ik vond het moeilijk om op te letten als ik met Charlie mijn dagboekje invulde.



helemaal oneens	oneens	neutraal	eens	helemaal eens
O	O	O	O	O

12) Charlie hielp mij goed met het invullen van mijn dagboekje.



helemaal oneens	oneens	neutraal	eens	helemaal eens
O	O	O	O	O

13) Wat vond je het leukst aan Charlie?

....

....

....

....

....

....

14) Wat vond je het minst leuk aan Charlie?

....

....

....

....

....

....

Dit is het einde van de vragenlijst. Dankjewel voor het invullen!

Appendix C: User manual

Handleiding

Samen met Charlie je dagboekje bijhouden

Hallo [Naam]!

Ik vind het echt super leuk dat wij samen jouw dagboekje bij gaan houden. Ik zal je proberen alles zo goed mogelijk uit te leggen, maar als je het eventjes niet meer weet kun je altijd in deze handleiding kijken.

Inloggegevens

Ik heb speciaal voor jou een e-mailadres gemaakt die je kunt gebruiken om in te loggen. Bij dit e-mailadres hoort ook een wachtwoord. Bewaar deze goed! Je kunt je e-mailadres en wachtwoord ook altijd terugvinden op het bureaublad van je laptop. Hoe je in moet loggen en met mij kunt praten laat ik je zo meteen zien!

E-mailadres	[naam].tno@gmail.com
Wachtwoord	123welkom

Oeps!

Gaat er iets mis en weet je het allemaal even niet meer? Geen paniek! Je kunt altijd even met Esther bellen. Zij kan je helpen het probleem op te lossen zodat wij weer samen verder kunnen. Handig hè?

Esther van der Drift (TNO)

06 - XX XX XX XX

1. Inloggen laptop

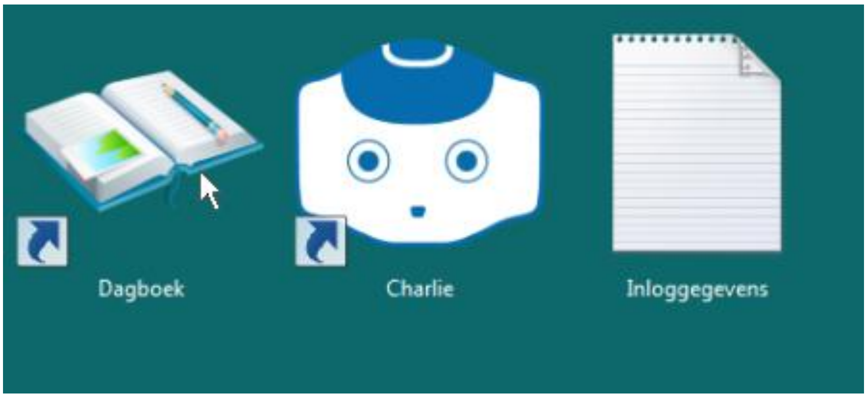
Als je de laptop aanzet en deze is opgestart kun je kiezen als wie je inlogt. Klik op jouw eigen naam. Je hoeft geen wachtwoord in te vullen, het gaat allemaal vanzelf.

Klik op jouw naam

2. Dagboekje starten

Als je eenmaal bent ingelogd zie je een aantal dingen op je bureaublad staan: je dagboekje, het programma om met mij (Charlie) te praten, en een bestandje met je inloggegevens.

Om je dagboekje te starten dubbelklik je op het icoon met het label **Dagboek**.



Dubbelklik op Dagboek

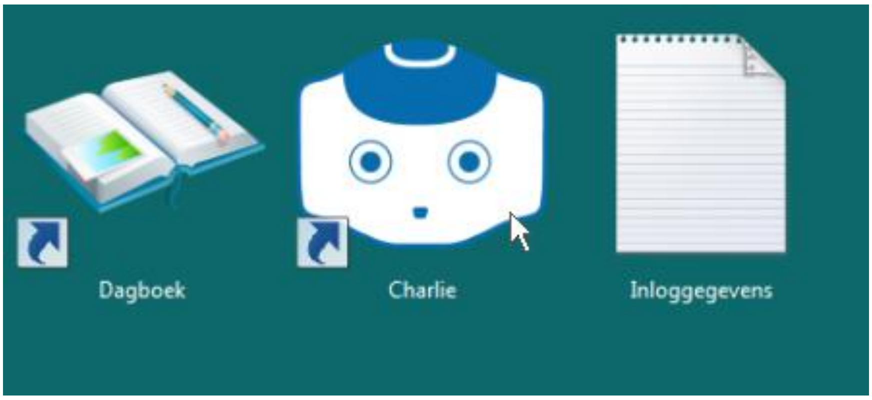
Nu zie je het hoofdscherm van het dagboekje. We moeten nog wel even inloggen. Klik op de **oranje knop** Inloggen en vul het e-mailadres en wachtwoord in die op pagina 2 staan.

Klik op Inloggen

3. Met Charlie praten

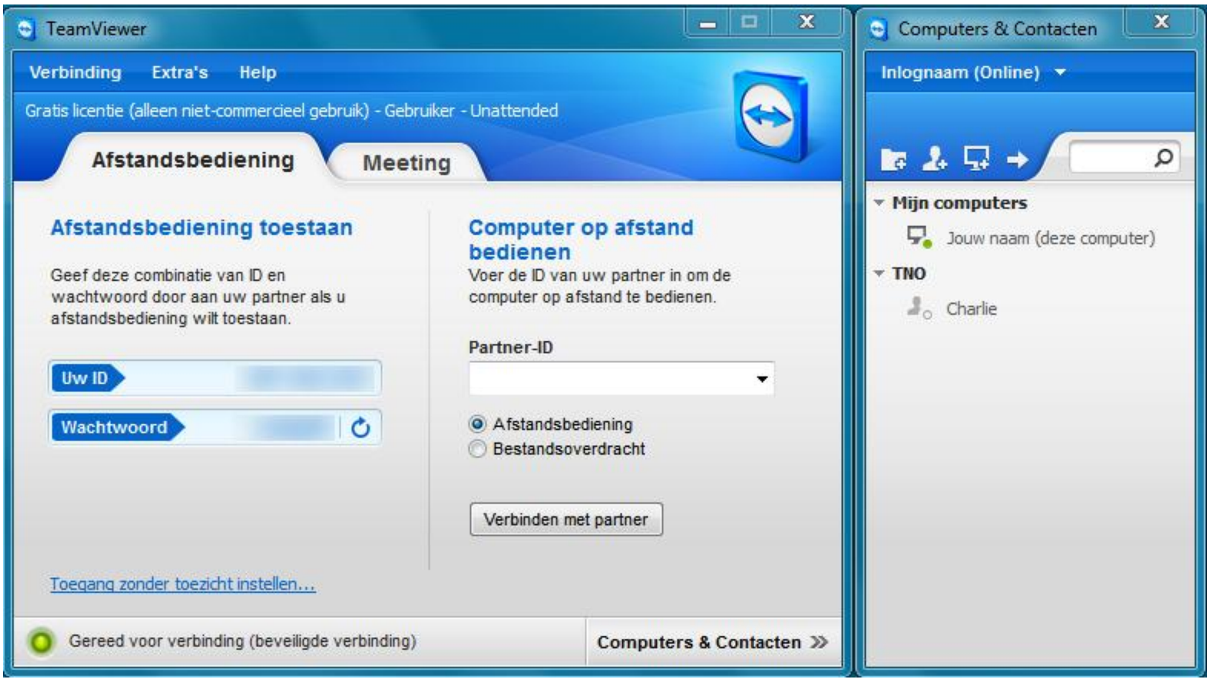
3.1 Programma starten

Om met mij (Charlie) te kunnen praten gebruiken we het programma TeamViewer. Dit programma kun je starten door op je bureaublad te dubbelklikken op het **Charlie** icoontje. (Vergeet niet alvast je dagboek te openen!)



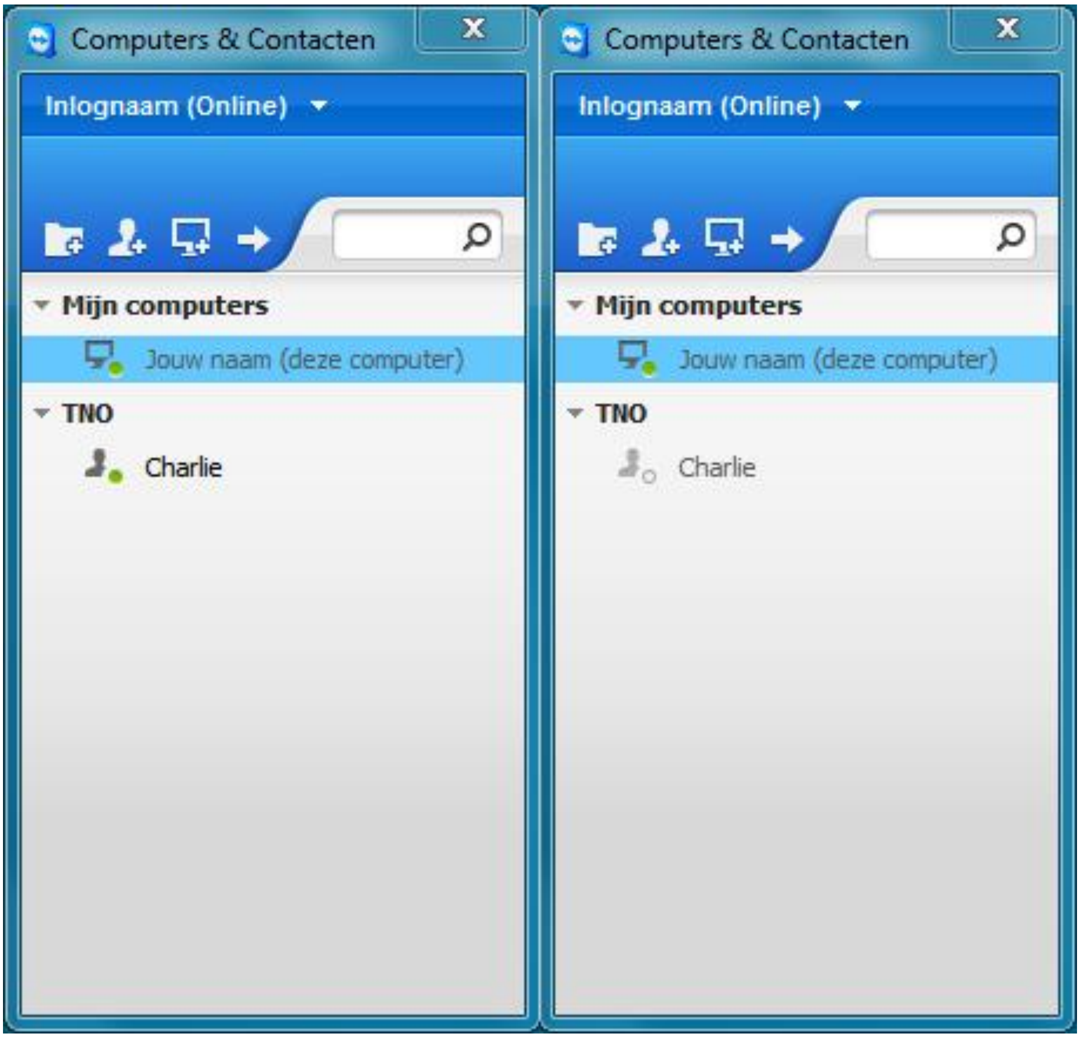
Dubbelklik op Charlie

Je ziet nu twee vensters, alleen de **rechtse** is voor ons belangrijk.



Zie je maar één venster? Klik dan rechts onderaan op **Computers & Contacten**.

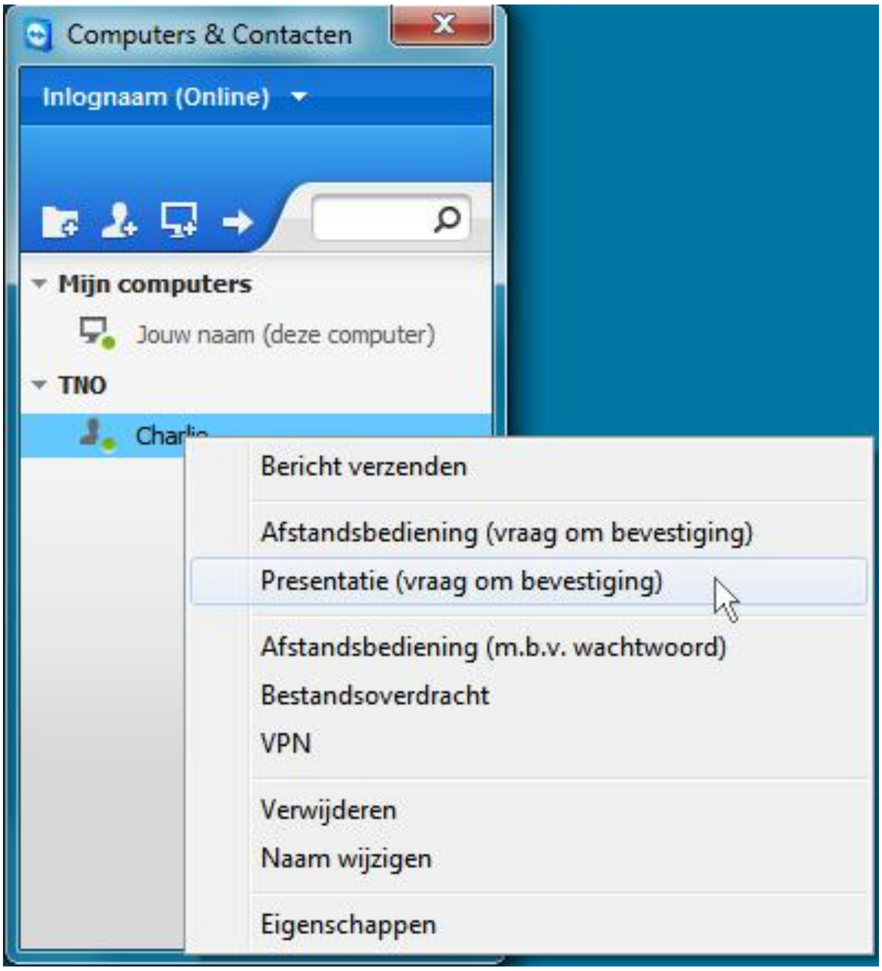
Onder het kopje TNO kun je zien of Charlie online is. Een groen of oranje bolletje betekent dat ik (Charlie) achter de laptop zit.



Charlie is online. **Charlie is offline.**

3.2 Charlie uitnodigen

Als je **rechts klikt** op mijn naam kun je mij uitnodigen voor een **Presentatie (vraag om bevestiging)**. Op die manier kan ik met jou meekijken wat jij in je dagboekje invult.

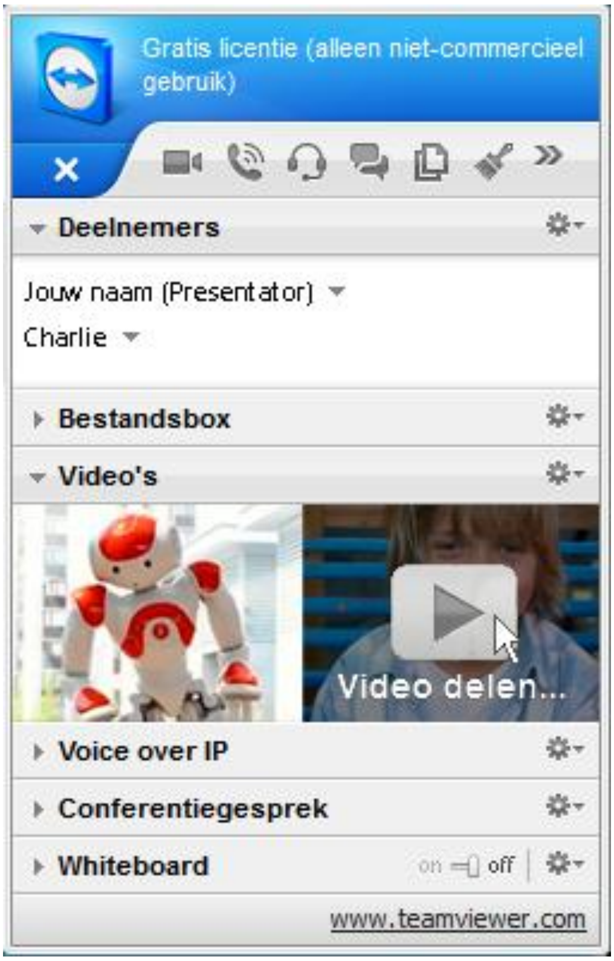


Klik met je rechtermuisknop op Charlie en klik op Presentatie (vraag om bevestiging).

<u>Jij kunt mij nu zien en horen, maar ik jou nog niet… Vergeet daarom niet de stappen op de volgende pagina te doen!</u>

3.3 Webcam delen

Nu we verbinding hebben kunnen we elkaar ook op de webcam zien! Alleen moeten we die nog wel even aanzetten. Ik zet die van mij eerst aan. Jij hoeft dan alleen nog maar met je muis op jouw video te gaan staan en **Video delen...** te klikken.

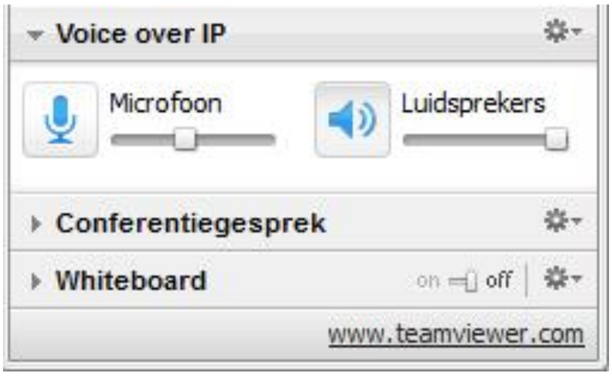


3.4 Geluid aanzetten

Nu het geluid nog en dan zijn we er helemaal klaar voor. Als je met je muis op het balkje **Voice over IP** klikt dan klapt het tabblad uit.

Zie je de streep door je microfoon staan? Dat betekent dat nu je microfoon nog uit staat. Als je met je muis op het icoontje klikt kun je deze aanzetten.

Als het goed is gegaan zie je nu een blauw microfoontje.



3.5 Afsluiten

Klaar met invullen en Charlie gedag gezegd? Klik op het kruisje links bovenaan je Teamviewer scherm.

Je krijgt nu waarschijnlijk een reclame melding, die mag je gewoon negeren. Klik op OK en sluit het programma af. Vergeet je niet je laptop ook af te sluiten? Dat bespaart stroom!

Appendix D: Technical protocols

Introduction session

1. Connecting NAO to the laptop
    a. Plug in router.
    b. Plug in and start NAO.
    c. Plug in laptop, start laptop and log in on TNO account.
    d. Connect laptop wirelessly with the router (Linksys), which should happen automatically.
    e. Connect NAO with the router via cable.
    f. Request NAO IP-address by pressing the button on its chest.
    g. Open WoOz shortcut on desktop.
    h. Open the file FrmNAOConnectorPlugin.dll in the Extensions folder.
    i. Change NAO IP-address if necessary and save.
2. Starting dialog
    a. Navigate up one folder and start WoOz.exe.
    b. Check all components in the interface except Dialog Tool.
    c. Check and open DialogComposer.
    d. Load Kennismaking.dialog laden (loading should happen automatically).
    e. Click the introduction subdialog to load the first remark. Press Send to play.
3. Execute dialog.
    a. Fill in User Model variables (name, age, hobbies, sports). Check the User Model in Game manager to open.
    b. Should the Send button remain gray, press Overrule Audio and click Send again.

Interaction session

1. Connecting NAO to the laptop
    a. Plug in router.
    b. Plug in and start NAO.
    c. Plug in laptop, start laptop and log in on TNO account.
    d. Connect laptop wirelessly with the router (Linksys), which should happen automatically.
    e. Connect NAO with the router via cable.
    f. Request NAO IP-address by pressing the button on its chest.
    g. Open WoOz shortcut on desktop.
    h. Open the file FrmNAOConnectorPlugin.dll in the Extensions folder.
    i. Change NAO IP-address if necessary and save.
2. Connecting to the internet and TeamViewer
    a. Plug in laptop, start laptop and log in.
    b. Plug in internet cable.
    c. Connect and set up webcam.
    d. Connect headset (audio only, no microphone).
    e. Start calorie calculation tool.
    f. Start TeamViewer.
3. Recording the screen
    a. Start ZD Soft Screen Recorder
    b. Check settings:
        i. Desktop App Demo
        ii. Full Screen Mode
        iii. What You Hear & What You Say
        iv. Output file: \\tsn.tno.nl\Data\Users\driftejgvd\Home\My Videos\Recordings
        v. Output resolution: original size
        vi. Output frame rate: 30 fps

vii. Auto-increment file number
viii. Start / Stop hotkey: F8
ix. Screenshot hotkey: F9
x. Toggle FPS hotkey: F10

c. Press F8 to start recording.

4. Starting dialog
   d. Navigate up one folder and start WoOz.exe.
   e. Check and start all components except Dialog Tool.
   f. Check and open Dialogmanager.
   g. Load Eerste-sessie.dialog.
5. Executing dialog
   h. Load User Model.
   i. Click subdialog to load the first remark. Press Send to play.

Appendix E: Data

Focus group summary *20/06/2012*

Objective

The objective of this focus group session was to gain insight into what children's expectations are of the robot and what they think the robot should be capable of if they would be playing with it. Furthermore, we were interested in whether the children keep a (normal) diary and a diabetes diary, what information is typically written in them and problems they experience with keeping a diabetes diary. Then we looked at how the robot might be able to help them overcome these problems. Last, we asked them what they would like to know from the robot. In other words: if you and the robot would be engaging in a conversation, what should the robot talk to you about?

Robot

General

There was some discussion as to whether "Charlie" was a boy or a girl (settled on boy), as well as what material he was made of. They thought the robot was cool and asked if they could buy one themselves. When they were shown a picture of the same robot in another color, one child proceeded to call it Charlina (female).

One of the children offered the suggestion to make a fake insulin pump so that the robot would have diabetes too. But then another child said that he was actually happy that this robot did not have diabetes for once.

Robot capabilities

The children thought the robot would be able to move, talk, make music, crack some jokes, walk, dance, jump (some discussion) and fight. They also asked me if it could take pictures, predict the future, paint, give a strong handshake, become angry and take care of their diabetes.

Robot wishes

When asked what they would like the robot to be able to do, they said: make a clown jump from its head, dress it up, have it make homework, do calculations, use as a slave, vacuum, clean, mow the lawn, carpentry, take care of people and give them medicine, remind them to bolus. One of the children indicated she did not really have any affinity with the robot and she could not think of things she wanted to do with it.

Games

When asked what games they could play with the robot, the children came up with: memory, tag, hide and seek, soccer, tennis and a self-invented game called 'barionetje' (ambush each other from the bushes like the Japanese in WWII).

Self-disclosure of the robot

The children wondered about how the robot would age and what it was like to be able to play music in your own head, but also about its hobbies, family (other robots) and even his favorite stuffed animal was a topic of interest.

Diaries

Regular diary

None of the children kept a diary. One of them said that he did in the past, but he just stopped doing it at some point. They were however interested in how the robot's day has been.

Diabetes diary

Information typically recorded in a diabetes diary is the blood sugar values, the date and the time. Adherence is very low. Usually the parents are responsible for recording the values. The information is only recorded two days before a doctor's appointment. The children indicated they do not really care much about the diabetes diary. They do not think it is important and they frequently forget to record their values. I noticed a trend that the earlier the child had been diagnosed with diabetes, the less they seemed to care. Illegible handwriting seems to be another problem when recording values. When asked where the children got the diabetes diaries from, they indicated they usually got them with insulin orders or from the hospital. All of them had large stacks of diaries at home.

Diabetes

Interestingly, one child said he thought it was nice to have diabetes. This appeared to be mainly because of the fact that he was allowed to go home or eat candy when he was not feeling well due to hyper- or hypoglycemia. There was some discussion on having high blood sugar and taking risks with your blood sugar. Also the difference between sugar and carbohydrates was a topic of discussion.

Experimenter observation logs

Algemene notities

Het opnemen van de sessies zorgde helaas voor nogal wat problemen, er is besloten hiermee te stoppen.

Er is meer smalltalk nodig over Charlie's dagelijkse bezigheden. Dus als Charlie bijvoorbeeld zegt dat hij heeft gevoetbald, moeten er ook teksten zijn voor de scores, of hij gescoord heeft, wie zijn medespelers zijn. Kinderen lijken oprecht geïnteresseerd te zijn in wat Charlie in zijn vrije tijd doet.

Eerste sessie **10-12-12**

Patrick *16:00-16:15*

Patrick reageerde neutraal-positief op Charlie. Hij had veel geduld als hij even op een antwoord moest wachten. Hij vulde netjes het dagboek mee in en wachtte steeds totdat Charlie het volgende onderdeel uitlegde. De vader van Patrick zat ernaast (buiten beeld).

Richard *17:00-17:30*

De internetverbinding met Richard was helaas erg slecht waardoor het beeld en geluid zo'n 10 seconden vertraging had. Dat had tot gevolg dat Richard wat minder in staat was het gesprek goed te volgen. Er was veel rumoer op de achtergrond en hij kon de robot niet zo goed verstaan. Hij vond het invullen van de basaalwaarden moeilijk en was ook niet zo enthousiast bij het zien van de robot. Hij had ook niet zo veel geduld en wilde snel alles invullen.

Sven *18:00-18:15*

Sven had zelf het dagboekje al ingevuld. We hebben samen nog wel even naar de dagbeschrijving gekeken, en hij heeft zijn pompje laten zien. We hebben afgesproken dat we het de volgende keer samen doen. Ik heb veel zelf moeten typen omdat ik er niet vanuit was gegaan dat Sven het dagboekje al van tevoren in zou vullen. Sven keek ook wat meer naar het scherm van de webcam. De moeder van Sven zat ernaast (buiten beeld).

11-12-12

Emmaly *16:00- 16:25*

Emmaly had moeite om Charlie te verstaan en ik moest vaak dingen opnieuw typen. Ze vond het leuk als de robot zwaaide en reageerde op wat ze schreef. De vader van Emmaly zat ernaast en hielp haar met invullen. Emily leek niet helemaal door te hebben dat ze ook op andere tijden kon klikken behalve de ontbijt, lunch en diner tijden. Ondanks de uitleg van Charlie ging het niet altijd goed. Ik vermoed dat het ook te maken heeft met een gebrek aan ervaring met de verschillende interactiecomponenten van de website (buttons, sliders, tekstvakjes). Ik heb in deze sessie nog niet echt smalltalk gebruikt omdat Emmaly het al moeilijk genoeg had met het invullen van het dagboekje.

Bas *17:10-17:40*

Het pompje van Bas heeft niet opgeslagen wat zijn bloedglucosewaardes waren en hoeveel hij gebolust heeft. We hebben afgesproken dat hij dat in een papieren dagboekje gaat bijhouden voor de volgende keer. De hond blafte op de achtergrond, dus ik heb de smalltalk over huisdieren gebruikt. Bas moest daar om lachen. Hij vond het duidelijk leuk wanneer Charlie hem bij naam aansprak. Hij zwaaide terug wanneer Charlie dat deed en glimlachte regelmatig.

Gerieke *17:50-18:10*

De vader van Gerieke zat ernaast. Hij gaf soms instructies dat ze iets moest zeggen omdat ze dat vaak niet uit zichzelf deed. Er was veel rumoer op de achtergrond (veel kinderen in huis). Verder was de internetverbinding helaas behoorlijk traag en duurde het vrij lang voordat het beeld en het geluid doorkwamen. Gerieke zwaaide wel terug naar de robot, maar toonde verder niet veel emotie bij het zien van de robot.

Tweede sessie **12-12-12**

Patrick *16:00-16:10*

Patrick vulde zijn dagboekje razendsnel in en zei nauwelijks iets terug tegen Charlie. In eerste instantie dacht ik dat hij Charlie misschien niet goed kon horen, maar hij was gewoon niet zo spraakzaam. Door de snelheid kreeg ik bijna niet de kans om te reageren op de dingen die hij invulde. Soms negeerde hij ook vragen die ik stelde (bijvoorbeeld of hij zijn dagboekje netjes had bijgehouden in de tussentijd).

Richard *16:55-17:10*

De verbinding met Richard was nu nóg trager dan de vorige keer. We hebben het programma een keer opnieuw opgestart omdat ik niet kon zien dat Richard was ingelogd in zijn dagboekje. Omdat er zoveel vertraging in zat kon ik niet adequaat reageren op de inhoud. Ik heb gezegd dat hij het maar moest zeggen als hij vragen had. Richard vroeg of hij zijn basaal elke keer moest invullen. Ik heb geantwoord dat dat alleen hoeft als het is veranderd. Daar was hij blij om. Volgens de moeder van Richard vond hij het de vorige keer erg leuk (via e-mail contact gehad).

Sven *17:55-18:10*

De vader van Sven hielp met het invullen van de waardes. Sven had de vorige keer het dagboekje al helemaal zelf ingevuld, daardoor wist hij niet dat er ook een makkelijkere manier was om de waardes in te vullen. Charlie heeft uitgelegd hoe het moet, en Sven was daar blij mee. Sven schreef veel op bij zijn dagbeschrijving, en Charlie heeft daarop gereageerd. De algemene indruk was dat Sven het erg leuk vond. Hij kwam erg vrolijk over.

13-12-12

Gerieke *15:55-16:10*

Gerieke gaf in eerste instantie aan dat ze klaar was zonder haar dagbeschrijving in te vullen. De vader van Gerieke zat in de buurt (buiten beeld) en gaf af en toe instructies ("zeg maar iets terug", "zwaai maar terug"). Ik heb de smalltalk gebruikt over rekenen, en ik heb gevraagd wat het belangrijkste was om op te letten met het eten als je diabetes hebt. Gerieke antwoordde daarop "je waardes". Wat natuurlijk ergens ook wel klopt, maar het goede antwoord was de koolhydraten. Ze leek verder niet echt onder de indruk van de robot.

Bas *17:00-17:10*

De vader van Bas was vandaag jarig, Charlie heeft hem daarmee gefeliciteerd. Er zat een vriendje van Bas naast hem terwijl hij het dagboekje invulde. Die vriend vroeg af en toe wat dingen over wat de robot deed of wat iets in het dagboekje betekende. Bas leek een beetje haast te hebben, waarschijnlijk door de verjaardag en het bezoek wat hij had. Hij vond het volgens mij wel leuk om met Charlie het dagboekje in te vullen.

Emmaly *18:15-18:30*

Het broertje van Emmaly was jarig waardoor ze waarschijnlijk wat later was dan anders. De moeder van Emmaly zat er soms naast en hielp soms met de waardes. Charlie heeft ook haar even begroet. Emmaly had vandaag een hele leuke dag en dat was aan haar af te zien. Ze lachte veel en reageerde enthousiast op Charlie.

Derde sessie **14-12-12**

Patrick *16:05-16:15*

Het ging nu wat beter dan de vorige keer. Patrick antwoordde wat vaker op vragen. Charlie heeft gevraagd waarom bewegen extra belangrijk is als je diabetes hebt. Dat wist Patrick niet, dus dat heeft Charlie uitgelegd. Patrick gaat van het weekend zwemmen en Charlie zei dat hij dat nog nooit heeft gedaan. Daarop moest Patrick lachen.

Richard *17:30-17:45*

Richard was erg laat vandaag. Het lukte in het begin niet om de microfoon en de speakers aan de gang te krijgen. Het ging fout bij het invullen van de kilocalorieën, maar ik kon door de slechte verbinding daar niet adequaat op reageren. Richard is nog even teruggegaan naar gisteren om de waardes van 's avonds in te vullen. Hij was ook vergeten zijn dagbeschrijving in te vullen, maar dat heeft hij voor vandaag (en het weekend in het vooruitzicht) wel gedaan.

Sven *18:00-18:10*

De vader van Sven hielp weer mee met de waardes voorzeggen die Sven moest invullen. Sven was erg spraakzaam. Hij vertelde een heel verhaal tegen Charlie over waarom hij vrolijk was vandaag en wat hij in de vakantie ging doen. Toen Charlie zei dat hij ook zin had in de vakantie vroeg Sven wat Charlie dan ging doen. Het was een erg leuk gesprek. Een van de waardes die Sven invulde ging niet helemaal goed, helaas wist ik niet hoe ik dit moest oplossen, dus hebben we het maar gewoon laten staan. Verder heb ik de smalltalk over bewegen gebruikt (vind je dat wel eens eng?), maar Sven zei dat zijn ouders hem daar goed mee helpen.

17-12-12

Emmaly *16:35-16:45*

Emmaly was laat omdat ze bij een vriendinnetje was blijven spelen, maar ze was gelukkig nog op tijd om voor de tijd het dagboekje in te vullen. Ze ging er vrij snel en gemakkelijk doorheen. Emmaly vertelde dat ze van het weekend feest had gevierd en vroeg wat Charlie in het weekend had gedaan. Charlie zei dat hij had gevoetbald, waarop ze vroeg of hij had gewonnen of verloren en wat de score was. Zij en haar moeder (die ernaast zat) moesten lachen om zijn antwoorden.

Bas *17:15-17:30*

Bas was zijn afspraak vergeten maar was gelukkig nog op tijd om het dagboekje in te vullen. Bas negeerde de meeste vragen die Charlie stelde. Ik dacht dat dat misschien kwam doordat hij Charlie niet goed kon horen, maar Bas zei dat dat wel zo was. Toen Charlie zei dat hij verloren had met voetbal vroeg Bas eveneens met hoeveel hij had verloren. Hij moest wel lachen toen Charlie over voetbal begon, en ook om zijn reacties. Hij kapte het gesprek vrij plotseling af op het einde en liet Charlie zijn afscheidsdialoogje niet afmaken.

Gerieke *17:45-18:00*

Er was veel rumoer op de achtergrond (familie ging of was net klaar met eten). Gerieke was niet zo spraakzaam. Ze vertelde wel wat ze in het weekend had gedaan maar hield het verder kort. Ze ging ook niet in op de dingen die Charlie over zichzelf vertelde. Het dagboekje invullen ging niet zo heel erg snel, maar dat had er ook mee te maken dat ze vrij veel waardes invulde. De verbinding was wederom traag waardoor het soms moeilijk te volgen was waar Gerieke mee bezig was op dat moment.

Vierde sessie **18-12-12**

Patrick 16:05-16:15

Patrick zei dat hij het jammer vond dat het alweer bijna voorbij was. Hij was erg afwachtend. Hij begon pas met het invullen als Charlie zei dat hij dat mocht doen. Ik heb de smalltalk over Charlie's lievelingsvakken gebruikt. Patrick zei dat rekenen ook zijn lievelingsvak was. Er was verder niet zo heel veel interactie tussen beiden.

Richard 16:55-17:05

De verbinding was wederom traag, maar wel beter dan de vorige keer. Richard reageerde een beetje boos toen Charlie vroeg of hij zijn webcam en microfoon aan kon zetten (en hij dat toevallig nét had gedaan). Richard vulde weer netjes de waardes van de vorige avond in, zonder dat daar om werd gevraagd. Toen Charlie zei dat deze twee weken best snel voorbij gaan zei Richard dat hij dat ook vond.

Sven 18:00-18:10

De dialogcomposer had wat problemen maar ik heb er redelijk omheen kunnen werken door af en toe zelf dingen te typen of overrule audio te gebruiken. Het contact met Sven was weer erg leuk. Sven vroeg wat hij moest doen met de waardes van vanavond omdat hij 's avonds een bruiloft heeft en dus nog niet gegeten had. Charlie heeft gezegd dat hij dat open mocht laten en als hij dat wil morgen nog in kan vullen. Sven antwoordde dat hij dat zeker zou doen. Sven vroeg ook hoe Charlie's dag was geweest en reageerde leuk op Charlie's antwoord. Charlie heeft nog gevraagd of alles in orde was met de vriend van Sven die een ongelukje had gehad (gelukkig wel), en heeft hem veel plezier gewenst op de bruiloft. De vader van Sven hielp weer buiten beeld mee met de waardes oplezen zodat Sven ze in kon vullen.

19-12-12

Emmaly *15:55-16:05*

Charlie kwam nog even terug op het vorige gesprek door te vertellen dat hij vandaag met voetbal gewonnen had. Dat vond Emmaly erg leuk. Ze vroeg wie er op keep stond (Lola), en vroeg daarna of Lola Charlie's vriendinnetje was en of hij haar leuk vond. Op het einde van het gesprek zei ze ook "doe de groetjes aan Lola!". Het contact was erg leuk, Emmaly reageerde enthousiast op de dingen die Charlie zei en lachte veel. Ze keek ook naar het webcam scherm want ik hoorde haar zeggen "kijk hij knikt" tegen haar moeder die buiten beeld zat. Emmaly had alle vragenlijsten al ingevuld (waarschijnlijk verkeerd begrepen). We hebben afgesproken dat ze het op de achterkant zou schrijven met de datum erbij.

Bas *16:55-17:05*

Bas vond het leuk dat Charlie gewonnen had met voetbal. Hij vroeg nog of Charlie gescoord had, waarop Charlie antwoordde dat hij één doelpunt had gescoord. Bas zei dat hij dat erg goed vond. Bas zei verder dat hij het inderdaad best snel voorbij vond gaan met het dagboekje invullen. Hij vond het ook leuk dat Charlie reageerde op zijn dagbeschrijving (Bas had een Frans proefwerk vandaag). Het ging allemaal vrij snel, maar mijn algemene indruk van deze sessie was positief.

Gerieke *17:30-17:40*

Wederom veel rumoer op de achtergrond van andere familieleden en een trage internetverbinding. Gerieke reageerde niet op de dingen die Charlie vertelde (over het voetballen). Ze was erg verbaasd en keek met grote ogen naar het scherm toen Charlie tegen haar zei dat ze vast heel mooi blokfluit kon spelen (in reactie op haar dagbeschrijving). Ik denk dat ze niet had verwacht dat hij er veel van zou begrijpen. Verder was er niet veel interactie tussen beiden. Gerieke had een beetje haast omdat ze vanavond naar het kerstfeest op school zou gaan.

Vijfde sessie **20-12-12**

Patrick *15:55-16:05*

Patrick zei dat hij het ook jammer vond dat het alweer de laatste keer was vandaag. Toen Charlie zei dat hij het dagboekje morgen niet in hoefde te vullen en vroeg "fijn hè?" zei Patrick "Mwha, nou.. nou…". Hij vond het duidelijk wel jammer. Toen Charlie zei dat hij later misschien Patrick nog eens zou zien zei hij dat hem dat leuk leek. Patrick reageerde leuk op de dingen die Charlie vertelde.

Richard *17:00-17:15*

Er waren wat problemen met de microfoon, maar Richard heeft dat zelf opgelost. Richard zei dat hij het erg snel voorbij vond gaan en dat ook het invullen van het dagboekje steeds sneller ging, zeker in vergelijking met de eerste keer dat ze het samen invulden. Hij zei dat hij het leuk vond als hij Charlie nog eens zou zien in het ziekenhuis. Hij vertelde vrij uitgebreid wat hij in de kerstvakantie gaat doen en vond het ook leuk om te horen wat Charlie ging doen.

Sven *18:00-18:10*

Ik heb de sessie met Sven opgenomen om in het project te gebruiken, dat is gelukkig helemaal goed gegaan. Het contact met Sven was erg leuk. Charlie heeft gevraagd wat Sven in de vakantie gaat doen, of er al een kerstboom in huis staat en of hij ook zo van sneeuwbalgevechten en sneeuwpoppen maken houdt. Sven zei ook dat hij het jammer vond dat het de laatste keer was en hoopte Charlie zeker nog eens terug te zien.

21-12-12

Emmaly *15:50-16:00*

Ik heb deze sessie (vrijwel geheel) opgenomen. Emmaly had de waardes van gister nog niet ingevuld dus dat heeft ze vandaag nog gedaan. Ik heb dezelfde smalltalk gebruikt als met Sven, maar Emmaly ging daar wat minder op in. Ze vroeg nog aan Charlie wanneer hij jarig was (ik heb wat verzonnen) en wenste hem alvast een hele fijne verjaardag. Emmaly vroeg ook wat hij in het ziekenhuis van plan was om te gaan doen, en op welke afdeling hij dan zou komen, maar dat wist Charlie (ik) nog niet. Ze zag het in ieder geval wel zitten om Charlie nog eens terug te zien.

Bas *17:10-17:20*

Bas was de afspraak weer vergeten. Hij reageerde op de meeste dingen die Charlie zei met "ja ik ook" en voegde daar verder niet veel aan toe. Hij moest wel lachen om de persoonlijke dingen die Charlie zei. Bas wenste Charlie ook een hele fijne vakantie, en zei dat het hem leuk leek om Charlie nog eens te zien in het ziekenhuis. Ik kreeg de indruk dat Bas vandaag minder waardes invulde dan anders.

Gerieke *18:00-18:10*

Gerieke was niet erg spraakzaam. Ze antwoordde op de meeste vragen die Charlie stelde alleen met "ja", of soms zelfs helemaal niet. Ze zei wel dat ze het leuk vond om met Charlie het dagboekje in te vullen, maar dat kan ook best een sociaal-wenselijk antwoord zijn geweest. Ze vulde wel veel in bij de dagbeschrijving vandaag.

Appendix F: Glossary

- **AADE(7):** American Association of Diabetes Educators (7 self-care behaviors). The AADE is a multi-disciplinary professional membership organization dedicated to improving diabetes care through education. The seven self-care behaviors are part of a framework that was developed by AADE to improve behavior change.
- **ADA:** American Diabetes Association. United States-based association working to fight the consequences of diabetes and to help those affected by diabetes.
- **ALIZ-E:** European project focused on the development and evaluation of social robot roles and personalized dialogues for long-term use with chronically ill children.
- **Hyperglycemia:** "High blood sugar". Condition in which an excessive amount of glucose circulates in the blood plasma.
- **Hypoglycemia:** "Low blood sugar". Medical emergency that involves abnormally diminished content of glucose in the blood.
- **IDDM:** Insulin Dependent Diabetes Mellitus. Also known as Diabetes mellitus type 1, an autoimmune disease resulting in the destruction of insulin-producing cells.
- **SMBG:** Self-monitoring of Blood Glucose. Refers to home blood glucose testing for people with diabetes.
- **WoOz:** Wizard of Oz. Research experiment in which subjects interact with a computer system that subjects believe to be autonomous, but which is actually being operated or partially operated by an unseen human being.