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Master Thesis

# Healthcare professionals gain control of children's diabetes self-management

Designing a healthcare management tool for healthcare professionals' assessment of T1DM knowledge, goals and development.


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# Healthcare professionals gain control of children's diabetes self-management

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**Abstract** – Children aged 8 to 12 with diabetes type I are motivated to get involved in their diabetes management to reduce the impact of their illness on their short- and long-term health. Self-management of diabetes is an active and proactive process and it involves shifting and sharing responsibility for diabetes care tasks and decision-making in frequent collaboration with healthcare professionals. The research question this study sought to answer is: 'How can a healthcare management tool support healthcare professionals in guiding children with diabetes self-management involving a social actor (robot/avatar)?'. To answer this question, a prototype of a healthcare management tool was developed and evaluated with end users (diabetes nurses) and an important stakeholder (diabetes doctor), following the situated Cognitive Engineering approach. Overall, this prototype of a redesigned PAL Control was perceived positively by the healthcare professionals and the findings suggested that a combination of an assessment with a robot or its avatar, setting goals, selecting actions and the progression page, is a suitable and effective approach to healthcare professionals in guiding children with diabetes self-management. Healthcare professionals mentioned that this system has provided them support in making the consult with children and parents more meaningful due to the fact that they can understand their needs better on forehand. However, evaluations for a longer period of time is needed in order to validate if the needs are completely fulfilled. Nonetheless, useful suggestions were found during the evaluation of the prototype and provided important pointers for further development.

**Keywords** - Healthcare management, diabetes self-management, social robotics, usability.

## 1. Introduction

### 1.1 Diabetes self-management

Type 1 diabetes mellitus (T1DM) is the most common type of diabetes affecting children globally (Scott, 2013). With T1DM the body mistakenly destroys its own cells in the pancreas that produce insulin. Unfulfilled blood glucose targets are still a crucial concern (McKnight, 2015). Children aged 8 to 12 with diabetes type I are motivated to get involved in their diabetes management to reduce the impact of their illness on their short- and long-term health (Dedding, 2009). Self-management of diabetes is an active and proactive process and it involves shifting and sharing responsibility for diabetes care tasks and decision-making in frequent collaboration with healthcare professionals. Self-management of diabetes consists of many different activities related to e.g. monitoring metabolic control, dosing insulin, and regulating diet and exercise (Schilling et al., 2002).

When children grow older their self-management skills and knowledge will develop. Although their self-management performance improves accordingly, they are still developing cognitively and emotionally at this age. Therefore, children are not always able to apply their skills and knowledge optimally. Activities related to giving the correct amount of insulin or handling low glucose levels in unfamiliar situations can be demanding. Furthermore, to keep a good quality of life, children will have to obtain a balance between self-management activities and experiences in important aspects of life, such as school and social life (Dedding et al., 2004). From a medical perspective, this may cause mismanagement of diabetes (Snoek and Skinner, 2007).

### 1.2 PAL & PAL Control for healthcare professionals

In order to support children with diabetes self-management, the European PAL (Personal Assistant for healthy Lifestyle) project started in 2015. The goal of PAL is to assist the child, healthcare professional and parents, to jointly perform diabetes management. As such, the child aged between 7 and 14 learns to be more self-reliant before adolescence. Figure 1 provides an overview of the components in the PAL system: PAL Control, PAL Inform, MyPAL, PAL robot and its avatar.

This study focuses on the component PAL Control, which is the functionality designed for healthcare professionals in guiding the children with T1DM self-management (blue circle in Figure 1). From the healthcare professional perspective, PAL Control is intended to be 1) a gatekeeper for information on the young patients to personalise their healthcare, 2) a tool to author and control the PAL robot and its avatar and aid the child in their self-management, and 3) a tool to provide explanations to the informal caregivers (e.g. parents) on the desired activities of the children (PAL 2016). The current state of PAL Control (version: 17-02-16) enable healthcare professionals to set learning goals for children during consults, whereby the goals are visualised in a 'goal tree' structure categorised by different levels. Furthermore, it enables the healthcare professional to enter data of the child including personal data and preferences such as sports and hobbies. Next, education materials can be added manually. Print screens of this current state and the 'goal tree' can be found in appendix A.

The current state of MyPAL App (version: 17-02-16) on the tablet for children consists of three functionalities: playing a quiz, filling in a diary and seeing the progress of quiz. For the parents a monitor & inform tool will be developed, which is also referred to as PAL Inform. Furthermore, the PAL system is composed of a social robot (NAO) and its (mobile) avatar, which all connect to a common knowledge-base and reasoning mechanism. This provides the possibility for children to make use of PAL in different settings, for example in the hospital and diabetes camps. Furthermore, children can interact with the social robot at home and/or at school through the virtual avatar of the robot. This project will take in total four years and involves the research partners TNO (coordinator), DFKI (Deutsches Forschungszentrum Für Künstliche Intelligenz), FCSR (Fondazione Centro San Raffaele), Imperial College, Delft University of Technology, next to end-users (the hospitals Gelderse Vallei, Meander, the Diabetics Associations of Netherlands and Italy), and SME's (Mixel and Produxi) (PAL, 2016).

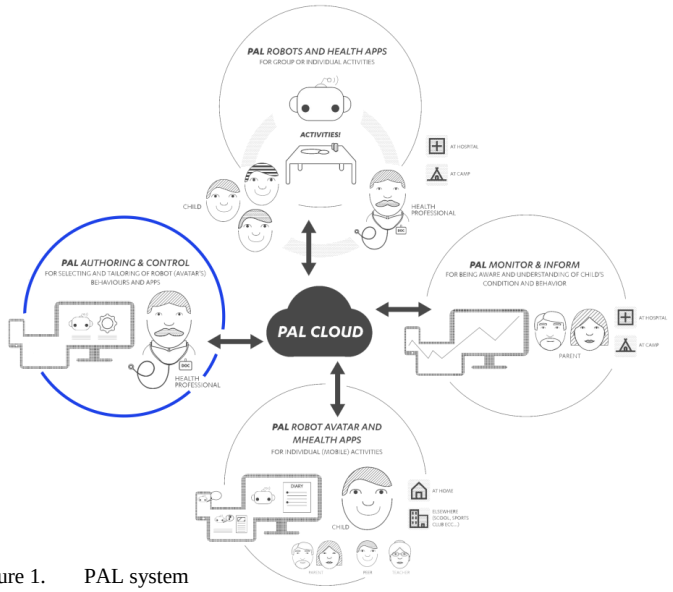


Figure 1. PAL system

### 1.3 Research question

This study aims to improve the current version of PAL Control through a needs assessment amongst healthcare professional, setting design specifications, prototyping and evaluating a clickable high-fidelity prototype of a healthcare management tool. This tool aims to support the healthcare professional in guiding children with diabetes self-management and authors the PAL robot and its avatar. The development is based on requirements collected during previous research in the PAL project (PAL, 2016). It will further contribute to fulfil the needs of children with T1DM, stimulate self-management, and enlarge their health and wellbeing through personal, pleasurable and social interaction under the guidance of healthcare professionals in PAL Control. The issue this study wished to address was: *'How can a healthcare management tool support healthcare professionals in guiding children with diabetes self-management involving a social actor (robot/avatar)?'.*

## 2. Background

### 2.1 Situated Cognitive Engineering

The design and evaluation of PAL Control follows the situated Cognitive Engineering (sCE) approach (Neerincx and Lindenberg, 2008), which aims to establish and test theories from the domain for which the application is developed. Furthermore, this approach provides quick, incremental, and iterative generate-and-test cycles. It has been previously applied in a wide variety of application domains and in multiple projects, such as a support system for human-robot team performance in complicated tasks (Mioch et al., 2014). Moreover, sCE maintains the sharing and reusing of design knowledge by a heterogeneous, multidisciplinary development group. Crucial is the generation, refinement, validation, maintenance, and reuse of consistent and brief design specifications. Such design specifications outline what the technology should do and the underlying design rationale, which is the 'why' and 'when'. Three main sections are distinguished: foundation, specification, and evaluation. As can be seen in figure 2, each of these sections has a small set of obligatory components that must be specified (Neerincx and Lindenberg, 2008).

The foundation section in the sCE methodology outlines the design rationale with regards to operational demands, relevant human factors knowledge, and envisioned technologies. The operational demands describe the current practice as it is. The human factors knowledge component in sCE describes available knowledge elicited from previous research about how to solve the problems that have been identified in the problem analysis. The component envisioned technology outlines the available possibilities of using existing technology and/or the need to elaborate new technology in order to achieve a system solution. Together, these three components describes the problem to be solved, the existing knowledge on ways to solve the problem and the technology needed to implement that solution (Neerincx and Lindenberg, 2008).

The section specification consists of design scenarios, use cases and requirements. It outlines the solution to the problem in the form of a system design that is based on the described relevant human factors knowledge and the envisioned technology. Design scenarios are short stories that gives a clear description of how the user will use the technology. Next, these scenarios are used to create more specific descriptions of step-by-step interactions between the technology and its users in the form of use cases. Thereafter, use cases are used to acquire functional requirements, which are specific functionalities the technology should give to its user (Neerincx and Lindenberg, 2008).

The last part of the sCE method is the evaluation, which aims to test and validate the system's design in order to improve the current design. It consists of the artefact, the evaluation method, and the evaluation results. The artefact is a prototype that integrates a given set of requirements, technological means and interaction design patterns. The evaluation method can be done in many different ways, such as an expert review. The evaluation results outline the results of the test. Due to the iterative and rapid research cycles, the evaluation does not necessarily integrate all requirements and use cases described in the system specification (Neerincx and Lindenberg, 2008).

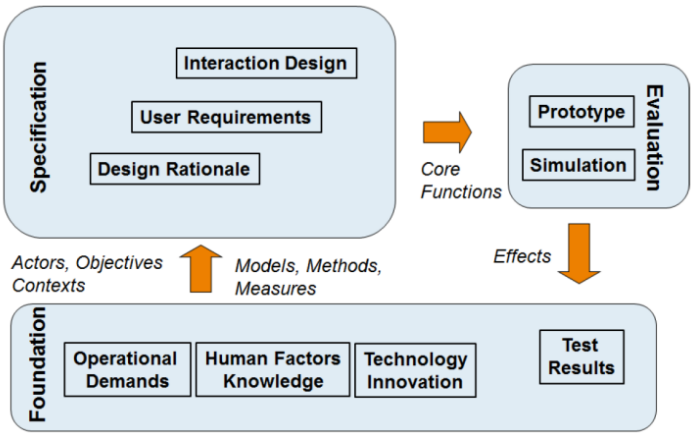


Figure 2. Situated Cognitive Engineering Method

### 2.2 Diabetes care

Optimal diabetes management begins with establishing the foundations of care. The healthcare professional preferably takes a holistic approach in providing care, considering all aspects of the patient's life circumstances. A team approach to diabetes management gives a thorough assessment and a development plan that describes the patient's values and circumstances. The components for the comprehensive medical evaluation that consist of aspects related to medical history, physical examination and laboratory evaluation, provides the healthcare team with information to optimally guide a patient with diabetes. Furthermore, information related to nutrition and psychosocial assessments should also be acquired (ADA, 2016).

The foundation of successful diabetes management consists of behavioral changes, an ongoing individual lifestyle, engagement of the patient, and assessment of the patient's level of understanding about the disease and level of preparedness for self-management. The core concepts of diabetes management are: diabetes self-management education (DSME), diabetes self-management support, counseling on stopping with smoking, medical nutrition therapy, education on physical activity, support on routine immunisations, and psychosocial care. Patients should also receive recommended preventive care services, such as immunizations. Furthermore, podiatric, ophthalmological, and dental referrals should also be provided. Healthcare providers should make sure that individuals with diabetes are screened for complications and comorbidities (ADA, 2016).

Patients with diabetes should receive medical care from a integrated team that may consist of physicians, nurse practitioners, physician assistants, dietitians, exercise specialists, nurses, pharmacists, dentists, podiatrists, and mental health professionals. The patient, family and healthcare professionals should work out the management plan. Different strategies and techniques should be used to enable patients to self-manage diabetes, which includes giving education on problem-solving skills for all aspects of diabetes management. Treatment goals and plans should be individualised, while considering patient preferences. In developing the plan, healthcare professionals should take the following aspects into account: the patient's age, physical activity, school/work schedule and conditions, social situation, eating patterns, cultural factors, diabetes complications, health priorities, other medical conditions, preferences for care and self-management, and life expectancy (ADA, 2016).

Current best practice of DSME is an approach based on skills that focuses on supporting those with diabetes to make informed self-management choices (Jensen et al., 2009; Charron-Prochownik et al., 2013). DSME has changed from a didactic approach, which is focused on giving information, to an empowering approach, which is focused on supporting those with diabetes to make informed self-management decisions (Charron-Prochownik et al., 2013). Diabetes care has moved to an approach that is more patient-centered and places the patient with diabetes and his or her family at the focus of the care model, working in collaboration with healthcare professionals.

### 2.3 Needs in children with diabetes

Children living with a chronic disease, such as diabetes, need additional support to enable them to achieve the main outcomes described by 'Every Child Matters', which is one of the most important policy initiative and development programs in relation to children and children's services of the last decade. These outcomes are: be healthy (enjoying good mental and physical health), stay safe (being protected from suffering), enjoy and achieve (getting the most out of life), make a positive contribution (being involved with the society and community) and achieve economic well-being (not being prevented from achieving prospects due to disadvantage. Nurses need to take these outcomes into account when working with children with diabetes (Owen, 2006).

The American Diabetes Association (ADA) (2016) announced that children have characteristics and needs that require different standards of care. However, the literature on self-management seldom makes a difference between self-management in children and in adults (Schilling et al., 2002). Research has shown that children with diabetes have a double greater prevalence of depression, and adolescents up to triple greater than youth who do not have diabetes (Grey et al., 2002). For patients diagnosed at a very young age with T1DM, having a strong support network is important for managing their diabetes effectively. It was found that often contact with certified healthcare professionals could improve the HbA1c value (glycated hemoglobin) and decrease hospitalisation rates (Howells et al., 2002; Svoren et al., 2003).

The goal of managing diabetes in childhood is to support the child in becoming an emotionally mature and physically healthy adult, free from difficulties associated with diabetes (Clarke, 2011). Children should be supported to manage their diabetes as part of their daily lives and most importantly, children must be involved in the decision-making of their management (NCC-WCH, 2004). A combination of specialist pediatric and diabetes care is needed for children with diabetes to be well-adapted and lead long and healthy lives in families which have come to accept the condition. Progressive accomplishment of self-management happens as developmental changes develop during childhood. It is crucial to be aware of the cognitive, psychosocial, and emotional skills needed to support the child with diabetes in accomplishing age-appropriate self-management. Appropriate expectations for the child with diabetes can be established through an understanding of normal growth and development as it relates to diabetes self-management tasks. Appropriate expectations and support in achieving self-management skills can support the child with diabetes move to self-management (Scott, 2013).

Self-monitoring of blood glucose (SMBG) has a critical role in the management of insulin-dependent diabetes mellitus. Patients have to test their blood glucose levels at least four times a day and set insulin doses for high and low blood glucose levels. Furthermore, frequent measurements, accurate record keeping of SMBG results is necessary for the patient and health care practitioner to evaluate diabetes control and make appropriate treatment adjustments on the long term. However, there is proof that adherence to both of these requirements is problematic for many patients (Gonder-Frederick et al., 1988).

Freeborn et al. (2013) conducted focus groups with 16 children in order to discover challenges and to understand experiences in the school setting of children and youth with T1DM from their own perspectives. They discovered that the three main challenges for children with T1DM are: self-care activities, low blood glucose and feeling lonely and/or different.

In a recent study it was concluded that living a good life with diabetes is demanding for the individual. However, experienced barriers can be relieved by aid from others in the personal sphere, and by professional support from diabetes care. Diabetes care was an important resource to develop the individual's ability and knowledge to manage diabetes, and to ease life with diabetes by giving support, guidance, medical treatment and technical devices tailored to individual needs (Engström et al., 2016). In the next paragraph technical tools used by healthcare professional in the guidance with diabetes self-management are discussed.

### 2.4 Diabetes management tools

Robots are becoming more inherent into everyday life. Time-critical domains, such as emergency response (Murphy, 2014) will include human-robot teams into missions, and robots will function as peer team members (Scholtz, 2003). One of the projects that provided valuable insights about how human-robot teams act in the healthcare domain is the ALIZ-E project, which started in 2010 to build the artificial intelligence (AI) for small social robots and to study how children would react to these robots (Aliz-e, 2014).

Another related project is REACTION (REACTION, 2014). Their goal is to develop an integrated ICT platform that facilitates improved long term diabetes self-management based on wearable, continuous blood glucose monitoring sensors and automated closed-loop delivery of insulin. This platform provides professional, integrated remote monitoring and therapy management to diabetes patients. Looking further at the functionalities within REACTION for healthcare professional, this platform can connect legacy healthcare systems, medical expert knowledge systems and provide closed-loop feedback in hospital environments to healthcare professional. Furthermore, it can aim at the outpatient regime and offer personalised feedback to healthcare professional.

A recent new monitoring system is the FreeStyle Libre Flash Glucose Monitoring System, which is a small sensor that automatically measures and continuously saves glucose readings day and night and is intended as a replacement for blood glucose meters (FreeStyle Libre, 2016). From the healthcare professional perspective it is useful that this monitoring system consists real-time glucose values, trend information and comprehensive reports, such as a summary of glucose data into percentiles throughout the day. Another monitoring system is COMMODITY12 (Commodity, 2015). It consists of ambient, wearable and portable devices. This project built a multi-layered multi-parametric infrastructure for continuous monitoring of diabetes type 1 and 2. The system used multi-parametric data to provide healthcare professional and patients, with clinical measurements for diabetes treatment. Therefore, it integrates software interoperation, state-of-the-art networks and artificial intelligence approaches in order to achieve a Personal Health System.

According to Catherine et. al (2012), who reviewed web-based diabetes guidance for patients and healthcare professionals, the quality of the support varied and showed a moderate impact on psychological and health outcomes. Another research showed that healthcare professionals have a positive perception towards web-based support for adolescents with T1DM (Nordfeldt, 2012).

## 3. Approach

Figure 3 provides an overview of the approach of this study which is based on the situated Cognitive Engineering (sCE) approach. In accordance with the sCE approach, the study was divided along three parts.

The first part is the foundation and consisted of a literature research and needs assessment (paragraph 2 and 3.1). Literature were researched about the diabetes care as usual and state of the art of technical tools used by healthcare providers in guiding children with diabetes self-management. The findings are described in the background section. A needs assessment of children was based on literature and the needs assessment of healthcare professionals were conducted through semi-structured interviews with four diabetes nurses.

In the second part the system redesign was specified (paragraph 3.2 and 3.3). Problem and design scenarios of how healthcare professionals interact with PAL Control were created based on the insights of the needs assessment, literature research and observations. Thereafter, the scenarios were visualised into storyboards, which were used to create more specific descriptions of step-by-step interactions in the form of use cases. Next, requirements were obtained from these use cases. The insights acquired from the 'specification' phase were used to formulate the core functionalities of a redesign of PAL Control.

In the last part of the sCE approach, the evaluation, the specified core functions were prototyped and evaluated with six healthcare

professionals (paragraph 4). The perceived usability of the prototype was evaluated qualitatively, with think-aloud method and semi-structured interviews, and quantitatively with the System Usability Scale (SUS).

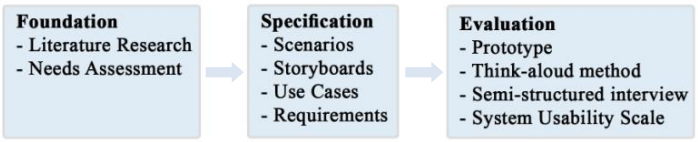


Figure 3. Overview approach

### 3.1 Needs assessment

A needs assessment of children is based on literature. The databases PubMed and Google Scholar were used and the keywords were: chronic diseases challenges, children' needs and diabetes self-management. Also, hospital documents related to children's diabetes self-management were analysed. A needs assessment of healthcare professionals was conducted face-to-face in a semi-structured interview. Four healthcare professionals (diabetes nurses) were interviewed with the aim of understanding the values and needs of healthcare professionals in guiding children with T1DM with the help of a healthcare management tool. Furthermore, based on observations a first pilot with PAL Control (version: 17-02-16) was analysed. Diabetes nurses were asked to fill in the basic profile page of the child and to set goals in the 'goaltree'structure in PAL Control. The observations consisted of screen recordings and videos, whereby the interaction between child and the diabetes nurse and parents was filmed while using PAL Control.

Participants were recruited from the two Dutch hospitals Gelderse Vallei and Meander. Eligibility criteria were participation in the experiments and experience of using PAL Control with a minumum of five children. Each interview was between 30 to 60 minutes and the topics for the semi-structured interviews were: functions, expectations, satisfaction, usability, setting goals and future improvements. The interviews were audio taped and transcribed for further analysis. The transcriptions were thematically summarised and analysed with codes, which gave an overview of the values and needs of the healthcare professionals. Figure 4 illustrates the most often mentioned problem scenario, which the nurses experienced when using the current version of PAL Control.

### 3.2 Scenarios and Storyboards

The values and needs (see table 1) elicited from the interviews, observations and literature are used as the foundation of the design specification, i.e., scenarios, storyboards, use cases and requirements. Based on the interviews and observations design scenarios could be created, which are described briefly in table 1. A more detailed design scenario (Fig. 5) illustrates how the new version of PAL Control can help the healthcare professional in selecting the right goals and the corresponding actions for the child, which resulted from the problem scenario described earlier in figure 4.

Furthermore, a visual representation of the scenarios was designed in storyboards in order to make the functionalities of PAL Control easy to understand for healthcare professional in the evaluation stage. The complete storyboards can be found in appendix B. The storyboards are based on the scenarios of how healthcare professional can use PAL Control in the situation before the first consult, during the consult and at the next consult.

### 3.3 Use Cases and Requirements

The scenarios and storyboards are used to create more specific descriptions of step-by-step interactions between PAL Control and healthcare professional in the form of use cases. Figure 7 illustrates the use case of the interaction between the healthcare professional and the child in setting goals and selecting actions after the child has played the assessment with the robot in the hospital. The other use cases can be found in appendix C. Thereafter, use cases are used to obtain requirements (see table 1).

**Problem scenario**

**'Sarah (nurse) has difficulties in selecting the appropriate goals for John (child).'**

'Sarah experiences difficulties in deciding which goals she should select in the goaltree of PAL Control for John (age 9), while talking to John at the same time. Furthermore, she finds the description of the goals not clear and some goals are missing. She tries to ask John several open questions in order to understand the needs of John, but he only answers in short sentences. Sarah tries to find a balance in making it a fun conversation for John, while testing his knowledge. Due to time limitation of the consult she can only ask a few questions. Therefore, she is still not certain if she has chosen the right goals for John to work on.'

Figure 4. Problem Scenario

**Design scenario**

**'John (child) plays assessment with robot at the hospital, which can support Sarah (nurse) to decide which goals John should be working on.'**

'Sarah explains to John that he is going to play a quiz on the tablet with the robot in the hospital. After playing the assessment John will see his scores of the topics (icons) and the robot would ask him if there are topics that he would like to work on. John can select the icons. If not, he can go to Sarah to discuss it. Sarah can discuss together with John by looking at the scores which goals he should be working on. After selecting the icons a preset of actions are presented and Sarah can personalise the actions or add new ones by discussing it with John. When both Sarah and John agree on the goals and actions, she can click on save and the goals with the actions will appear in MyPal.'

Figure 5. Design Scenario

## 4. Evaluation

### 4.1 Prototype

The scenarios, storyboards, use cases and requirements derived from the interviews with healthcare professional, observations and literature provided input and focus for the prototype development. The selected requirements (see table 1) were being prototyped as core functionalities in PAL Control.

It was decided to create a prototype consisting of four main components: PAL Control on desktop; assessment with PAL Robot at hospital; assessment with PAL avatar at home; and MyPAL environment with the new functions 'information' and redesign of 'goals'. The interface was designed to allow healthcare professional to develop a rapid understanding of the value of new functionalities of PAL Control in their practices. Furthermore, in order to get a complete impression of functionalities that the healthcare professional might find useful, it was decided to prototype a complete PAL Control including redesigning features such as select child, sign out/sign in page, language option and a redesign of the profile page where healthcare professional can enter basic information of the child. These redesign requirements were elicited from the observations and requirements of previous research in PAL project. The goal of evaluating a complete PAL Control was to facilitate a more consistent and realistic system for the healthcare professional.

A paper prototype was created first to rapid sketch out the main ideas. Furthermore, by creating a paper prototype that implements the scenario an early user test could be conducted. Next, a mockup was created with the tool Balsamiq Mockups[1], which is a rapid wireframing tool that produces the experience of sketching on a whiteboard using a computer. The mockup was useful in discussing the core ideas and helpful in the decision process of which functionalities to evaluate. Appendix D shows the lo-fi prototype and the elements they contain. After the main concepts were decided, a high fidelity prototype was created.

[1] https://balsamiq.com/

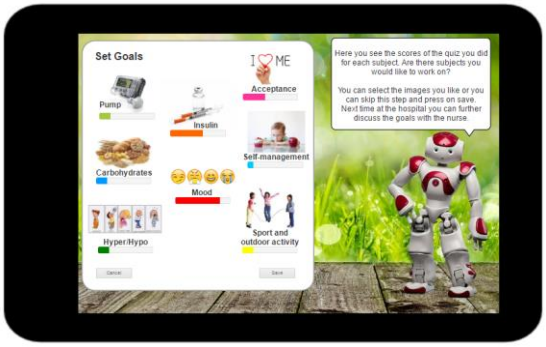


Figure 6. Prototype print screen: set goals with PAL Avatar

First, static screens were designed in photo editing software Adobe Photoshop[2] and graphic design software Adobe Illustrator[3]. Next, Axure RP Pro[4], which is a wireframing and rapid prototyping tool aimed at web and desktop applications, was used to make the static screens clickable. The complete screens of PAL Control prototype can be found in appendix E. The prototype consisted a variety of functionalities, which were categorised into 11 core functions (see table 1 and Fig. 6).

An important design choice within this prototype is by facilitating 'Nurse View', which is where healthcare professional can sign in/out within the MyPAL environment of the child in order to start the diabetes assessment with PAL robot, set goals, select actions and edit progress. The aim is to improve the interaction between the child and healthcare professional and to involve the children more in the decision process of goals during the consult by creating this authoring function in MyPAL on the tablet. This can enable the child to understand how the goals are set and how the activities appear in MyPAL. Furthermore, it can also invite the child to touch the screen together with healthcare professional to set goals and select actions. Another design choice was to minimise the volume of text in the screens through the use of graphical representation in the form of pictograms in order to stimulate the interaction between the child and healthcare professional.

This prototype is evaluated to assess to which extent the core functions of the redesigned PAL Control, which aims at fulfilling the needs as described in table 1, can support the healthcare professional in guiding children with diabetes self-management. Furthermore, the prototype evaluation aims to determine whether there are specific aspects more useful than others and what needs to be improved.

## 4.2 Evaluation Method

Participants were recruited between April and June 2016. In total six healthcare professionals from the hospitals Gelderse Vallei (3) and Meander (3) participated in the evaluation. These healthcare professionals consisted of five diabetes nurses and one doctor (a pediatrician and who is also a medical director), whereby four of them were also interviewed earlier to elicit their needs (paragraph 3.1). All diabetes nurses that participated had experience with using PAL Control with a minimum of five children during the first PAL-pilot. Additionally, we decided to also incorporate a doctor's perspective by interviewing one doctor who worked with two of the diabetes nurses.

The six evaluations were conducted face-to-face at the hospitals Gelderse Vallei or Meander. Prior to each evaluation, an introduction was given to explain the prototype and the goals of the evaluation. Furthermore, participants were asked for permission to record (video & audio) the evaluation. All interviewees were asked to speak freely and were assured that the recordings remained confidential. The evaluation took approximately an hour and consisted of: 1) showing the storyboards that represent the context of PAL Control being used before, during and after the appointment; 2) applying the 'think-aloud-method, whereby the healthcare professionals were asked to use the clickable prototype to test the different functionalities, while continuously thinking out loud; 3) conducting a semi-structured interview in order to understand whether they are interested in these functionalities and what the improvement points were. Interview topics were: need fulfillment, functionalities, expectations, satisfaction, usability and future improvements; 4) completing the System Usability Scale (SUS), which provides a reliable tool for measuring the usability. It consists of a 10 item questionnaire, whereby a response is given on a scale of 1 to 5, according to the user's degree of satisfaction (Borsci et al., 2009).

Data from the semi-structured interviews and think-aloud-method were transcribed during the evaluation, which supported early familiarisation with the data. Certain parts were listened again from the recorded audio and video file to ensure that a correct transcription has been noted. Transcript analysis was an iterative process using thematic analysis, which involved identifying themes and codes across all transcripts and SUS data. Codes were meaningful groups of data that described the core of the data. Atlas.ti[5] was used to facilitate the organisation of codes and themes.

- **Goal:** Child and healthcare professional set goals and select actions together in MyPAL
- **Actor:** PAL robot, MyPAL, Sarah (healthcare professional) and John (Child)
- **Pre Conditions:** The robot, a tablet with the app MyPAL, John and Sarah are in the hospital.
- **Post Conditions:** With the help of the PAL robot, Sarah could easily set the appropriate goals for John and select the corresponding actions. John understood what the goals are and felt fully involved in the decision process of selecting his learning goals.
- **Action Sequences:**

1. Sarah introduces the robot to John and explains that he will play a quiz about diabetes management with the robot.
2. Sarah asks John if she can use his tablet to sign in 'Nurse View' within MyPAL to start the assessment. John gives her the tablet.
3. Sarah star the quiz and goes to another room, while John does the assessment (e.g. 3 questions for each topic) with the robot.
4. After answering the questions, John sees his scores. The scores are presented in a progress bar, an image of the topic and the level he has reached of that specific topic .
5. Robot asks if John has any subjects he would like to learn more about and invites John to select a few images, whereby the progress bar is visualised below the images.
6. If there is no response from John, the robot will suggest John to show the goals to Sarah and discuss this together.
7. John selects a few images and press on continue.
8. Robot asks John to show these goals to Sarah and to ask her opinion of the selected goals.
9. John and Sarah sit together and Sarah explains that with the goals the child can improve on his diabetes management and that these goals can be achieved by playing PAL activities with the PAL Avatar.
10. Sarah agrees with the selected goals after looking at the progress bar that is visualised below the goals.
11. After pressing on 'save', the next screen shows a preset list of actions (e.g. watch a video, upload diabetes values or play the quiz), whereby the robot has already selected a few activites based on the scores of the assessment from John.
12. Sarah asks John if he agrees with these actions and if he has any actions that he would like to do that are not in this list yet.
13. John and Sarah discuss together about the actions and Sarah can deselect/edit the actions or add a new action if it is not in the list yet.
14. Sarah compliments the child for his goals and indicates that she is going to sign out 'Nurse View' now and that John can start doing the selected activities with the PAL avatar when he gets home.

**Requirements:**

- PAL shall provide a visual overview of icons representing topics related to diabetes management.
- PAL shall invite the child to first pick icons they want to talk about, followed by suggesting the child to discuss about the selected icons with the healthcare professional.
- PAL shall provide an overview of different activities that are related to the topic and suggest some activities based on the child preferences, whereby the healthcare professional can add and

Figure 7. Use case: Set goals and selecting actions

[2] http://www.adobe.com/products/photoshop.html

[3] http://www.adobe.com/products/illustrator.html

[4] https://axure.com/

[5] http://atlasti.com/qualitative-analysis-software/

| Values & Needs | Scenarios | Requirements | Core Functions |
|---|---|---|---|
| ***Access*** - The need of having access into MyPAL in order to understand the activities that the child is doing in MyPAL. | Before the consult the healthcare professional can already start experiencing the functionalities in MyPAl in order to get a **better understanding** when the child talks about certain activities **in MyPAL**. | PAL Control shall provide a functionality whereby the healthcare professional can **see how MyPAL looks** like for the child anytime. | MyPAL View |
| ***Information*** - The need of getting insights about the data that the child has typed in MyPAL. | The healthcare professional can already start looking at the **statistics**, which are elicited from the information that is **typed by the child** in MyPAL. This will help the healthcare professional to better understand the needs of the child during the consult. | PAL Control shall provide an overview of child-user's **progression on PAL-objectives**, **emotion, daily activities and system usage**, whereby important/critical situations can be filtered. | MyPAL Statistics |
| ***Information*** - The need of getting insights of the knowledge and concerns of parents. | Healthcare professional can already start reading the **concerns** that parents has sent before the consult or during the consult and use these concerns as **topics to talk about with parents**. Furthermore, parents can play an **educational quiz** to test their knowledge about diabetes, whereby the healthcare professional can see the results as well to better fulfil the needs of the parents. | PAL Control shall provide an **overview of concerns that the parents** have send.<br>PAL Control shall provide an **educational quiz for parents** and an overview of the results of the quiz for the healthcare professional. | PAL Inform |
| ***Information*** - The need of having a clear overview of the progress of each goal of the child. | Healthcare professional can see in the goal tree on **which level the child** is. When the child has fulfilled the actions the goal will switch from orange to green. Furthermore, the healthcare professional can also manually turn goals green if preferred. | PAL Control shall provide an **overview of goals, a clear description, ability to add more goals and the progression** of child's performances. | Goals |
| ***Education*** - The need of selecting (digital) educational material for children. | At the clinic before/during/after the consult, healthcare professional can contribute to child's autonomy in managing diabetes by **selecting appropriate educational materials** of the database or **add new digital materials** (e.g. scanning a flyer) in the database, whereby this source can be shared with other healthcare professional as well. The selected material for the child will be sent to MyPAL app of the child. | PAL Control shall provide **a portfolio of educational materials (for children)** from which the healthcare professional can select/add, whereby **PAL Actor will motivate the child** to read these materials in MyPAL. | Education [Child] |
| ***Education*** - The need of selecting (digital) educational material for parents. | At the clinic before/during/after the consult, the healthcare professional can fulfil the needs of **parents** by **selecting educational materials** of the database or add new digital material (e.g. scanning a flyer) in the database. | PAL Control shall provide a **portfolio of educational materials (for parents)** from which the healthcare professional can select/add and send as an attachment (under 'report'). | Education [Parent] |
| ***Information*** - The need of having a guideline tool of topics where healthcare professional can talk about during the consult with parents/child. | Before consultation healthcare professional can already **type a checklist** in PAL Control and add notes that can be used as a **guideline of topics to talk about during the consult** with parents. Furthermore, an overview of selected goals and actions of the child can be **sent to the parents** and be used as a guideline to talk about in the next consult. | PAL Control shall provide an option to **send a summary of notes** to the parents, an overview of the **selected goals and the corresponding actions** in order to give the parents a better understanding of what their child is learning and the **educational materials** as an attachment (if any material was selected in 'education'). | Report |
| ***Development*** - The need of a fun assessment in order to test the diabetes knowledge of the child in order to select the appropriate goals for him. | The healthcare professional can decide to let the child do the **assessment at the hospital with the robot** or healthcare professional can activate the assessment in Pal Control in order to let the child play the **assessment at home with the robot-avatar** in their own time. | **PAL Robot/ PAL avatar shall motivate the children in finishing the assessment** and praise children in ways that acknowledge their efforts. | Assessment in hospital/home |
| ***Equality*** - The need of making children more involved of their own learning goals and actions.<br>***Development*** - The need of easily selecting goals, whereby the child has a basic understanding what the goals represent. | During consultation, child and healthcare professional are at the same level. healthcare professional performs **shared decision-making about the learning goals** with child.<br>The **child understands** what the goals are by looking at the images that he can select. | PAL shall provide a **visual overview of icons representing topics** related to diabetes management.<br>PAL shall invite the **child to first pick icons they want to talk about**, followed by suggesting the child to discuss about the selected icons with the healthcare professional. | Set Goals |
| ***Equality*** - The need of having a possibility to add actions by the healthcare professional. | Healthcare professional performs **shared decision-making about the actions** that helps in achieving the learning goals with child and if the child has any suggestions of actions he would like to do, the healthcare professional can add these together with the child to the list. | PAL shall **provide an overview of different activities** that are related to the topic and suggest some activities based on the child preferences, whereby the healthcare professional can add and personalise the actions if preferred. | Select Actions |
| ***Achievement*** - The need of having a clear overview of the child's progression in achieving his goals and the possibility to edit it for the healthcare professional.<br>***Information*** - The need of having a clear overview of the progression of achieving goals for the child in MyPAL. | At the beginning of the next consult the healthcare professional can have a look at the progress together with the child to see which goals the child has achieved and which actions he found difficult to fulfil. The healthcare professional can give **motivational feedback** and together with the child they can decide to add more actions or move on to achieve another goal.<br>The healthcare professional can decide based on the progress of the child to enable the child to do another assessment with the robot at the hospital or robot-avatar at home. | PAL Control shall provide an **overview of child-user's progression** on goals and achievements **for the healthcare professional**.<br>PAL Control shall provide an **overview of child-user's progression** on goals and achievements in a way **that motivate the child** to continue achieving the goals. | Progress for healthcare professional & Child |

Table 1. Overview values, needs, scenarios, requirements and core functions

## 4.3 Evaluation Results

*4.3.1 Usage of Tablet*

The participants appreciated that the shared decision making process of goals and actions is offered on a tablet instead of on a desktop. The healthcare professional mentioned that the tablet created a unconstrained atmosphere and is more inviting for the child to participate actively in setting goals/selecting actions. One diabetes nurse shared her observation of the previous experiment that she noticed that some children found it easier to share their emotions to the healthcare professional by looking at the tablet instead of looking at the healthcare professional directly. Furthermore, the nurse said that she also found it more comfortable to look at the tablet while talking to the child.

*4.3.2 Role of PAL robot/avatar*

Overall, the participants were positive about the assessment functionality with the robot/avatar. The healthcare professional mentioned that it is appreciated that the robot is involved in setting goals and selecting actions at the beginning. They believed that the presence of PAL robot or its avatar motivates the child. Regarding the preference between PAL robot or its avatar, the healthcare professional indicated that a combination of both would give the best outcome. Their expectation is that the child would like the robot the most. One healthcare professional mentioned: *'You are making the consult more fun for the child'*. However, you do not want the child to travel to the hospital every time and therefore, doing the assessment with PAL avatar was perceived as a good solution to give the child the option to do it at home in their own time. She also liked the idea that you can see what the child has achieved or has difficulties upfront in order to have a more meaningful consult.

*4.3.3 Usability*

Overall, the usability of the prototype was perceived positively. The healthcare professional appreciated the colour use and pictograms. Furthermore, the healthcare professional mentioned that it is nice that a picture of the child could be added as a profile picture in the system. A healthcare professional said: *'My first impression is that it is nice to use and easy to understand. After using it in practice, it will become clear if this impression stays the same.'* The mean SUS score attributed by the five diabetes nurses also confirms this (see table 2). The score was above average, at 79. This score can be interpreted as a grade of B in a range of A to F, whereby A is the highest score achievable (Borsci et al., 2009). Explanation of the calculation of the user scores and SUS scores can be found in appendix F.

Main improvements from a usability perspective are the way how the data is visualised. One healthcare professional indicated that she did not like graphics and that she preferred a list or a circle diagram. Furthermore, a healthcare professional mentioned that it also should be evaluated with children to see how they perceive graphics as a way to see their progress or that they perhaps prefer another way of information visualisation.

*4.3.4 Functionalities*

Overall, the functionalities were perceived positively by the participants. One healthcare professional mentioned: *'It is a nice way to make the outpatient visit more child friendly and this approach fits well in these modern times.'* Another healthcare professional said that there are too many functionalities, but she also mentioned that the functionalities sounded useful and perhaps some of them could be moved to other components of PAL system (e.g. PAL Inform/MyPAL). Another participant mentioned that the system was coherent and that it has a logical structure. A nurse said: *'It seems that there has been a lot of thought put into all these different components. There are different possibilities to use the system, which makes it attractive'.* It was for all participants difficult to differentiate which functionalities they preferred. A diabetes nurse said: *'The way I see this system, without experience using it in practice, is that all functionalities are needed and complete each other. My opinion might change when I have worked a few weeks with this system.'*

**Profile page** – A redesign of the current profile page was created and one healthcare professional mentioned that the profile page is not necessary, because they already have that in another system. However, other healthcare professionals indicated that it was useful to look into it when they are in PAL Control, because otherwise you have to open two systems at the same time. Another healthcare professional suggested to add more information in this profile page about for example the information of the school the child is going, which can be interesting information for the healthcare professional when the child goes to secondary school.

**Report** – In the 'report function', a healthcare professional suggested for an option that the things you have written as notes/checklist can sometimes already be sent to parents to give them an outline of what they can expect during the next meeting. Another healthcare professional mentioned that it would be valuable to synchronise certain information/functionalities of EMR within PAL Control to avoid manually filling in things for the second time. One healthcare professional mentioned that only the sub functionality of sending an overview of goals & actions of the child after the consult is enough for her. Another participant liked the idea to send a summary of the consult to the parents, such as important notes/advise. She stated: *'Parents can read the summary again whenever they want and they will not lose the information.'*

| | | HCP 1 | | HCP 2 | | HCP 3 | | HCP 4 | | HCP 5 | | Average | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | User Score | SUS Score | User Score | SUS Score | User Score | SUS Score | User Score | SUS Score | User Score | SUS Score | User Score | SUS Score |
| 1 | I think that I would like to use this system frequently. | 5 | 4 | 4 | 3 | 5 | 4 | 3 | 2 | 5 | 4 | 4,4 | 3,4 |
| 2 | I found the system unnecessarily complex. | 2 | 3 | 1 | 4 | 1 | 4 | 1 | 4 | 1 | 4 | 1,2 | 3,8 |
| 3 | I thought the system was easy to use. | 2 | 1 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 3,6 | 2,6 |
| 4 | I think that I would need the support of a technical person to be able to use this system. | 1 | 4 | 2 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 2,4 | 2,6 |
| 5 | I found the various functions in this system were well integrated. | 4 | 3 | 5 | 4 | 4 | 3 | 3 | 2 | 5 | 4 | 4,2 | 3,2 |
| 6 | I thought there was too much inconsistency in this system. | 1 | 4 | 1 | 4 | 2 | 3 | 2 | 3 | 1 | 4 | 1,4 | 3,6 |
| 7 | I would imagine that most people would learn to use this system very quickly. | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 2 | 5 | 4 | 4,2 | 3,2 |
| 8 | I found the system very cumbersome to use. | 4 | 1 | 1 | 4 | 1 | 4 | 3 | 2 | 1 | 4 | 3,25 | 3 |
| 9 | I felt very confident using the system. | 4 | 3 | 3 | 2 | 4 | 3 | 3 | 2 | 5 | 4 | 3,8 | 2,8 |
| 10 | I needed to learn a lot of things before I could get going with this system. | 2 | 3 | 2 | 3 | 1 | 4 | 2 | 3 | 1 | 4 | 1,6 | 3,4 |
| | **SUS Score** | | **75** | | **82.5** | | **82.5** | | **62.5** | | **92.5** | | **79** |

Table 2. SUS Score

**Education Child and Parent** – The idea of a database with educational material, which can be send to MyPAL for the child was perceived as positive. Additionally, this same functionality for parents was also perceived as useful. One healthcare professional said: *'It's very nice to be able to supply information in a digital way, because papers can be lost quite easily.'* Furthermore, healthcare professional liked the idea that they can add more material if they want and that this database is shared with other healthcare professionals, but it should remain clear who (hospital Gelderse Vallei or Meander) has uploaded the educational material. A healthcare professional mentioned an important challenge within this function is to make sure that the database overview stays clear and that it contains qualitative good material. Furthermore, it should be easy to find material related to certain topics in the database. Another participant mentioned a critical limitation was that practical aspects, such as how to inject insulin could not be so easily learned by only watching a video.

**Assessment** – The assessment starts with two questions about the age and the device (pump or pen) that the child is using. Some nurses mentioned that these two questions might be too difficult for a young child and perhaps these two steps could be done together with the healthcare professional. Another healthcare professional mentioned that these two questions are unnecessary due to the fact that this information is already in the system. Overall, healthcare professionals liked the idea of the child doing an assessment with the robot or its avatar, because the score overview can help healthcare professionals to determine more easily which topics the child needs to work on.

**MyPAL view –** The functionality of MyPAL view was perceived as useful by all participants. One healthcare professional said: *'I find it useful to have access to see how the activities in MyPAL look like for the child, so I have a better understanding when the child talks about certain activities in MyPAL during the consult.'*

**PAL Inform** – Overall, healthcare professionals mentioned that PAL Inform was useful. They indicated that these data help them to better understand the needs of the children and their parents. Within PAL inform there is a functionality whereby parents can already send their concerns about their child to healthcare professional when something comes into their mind. A nurse said: *'Often parents have already forgotten their questions during the consult, especially after the meeting with the doctor first (parents talk to doctor first before talking with the diabetes nurse). Now they can easily ask at home already.'* The idea of parents doing a diabetes quiz was perceived diversely. One healthcare professional mentioned that she does not expect that parent have the need to play the game, while another healthcare provider mentioned that it is very useful to educate parents as well and that by playing a quiz can be a good way to find out the gaps in parents' diabetes knowledge.

**PAL Statistics** –Interviews with the doctor and nurses indicated that there are main differences in their needs. Most of the nurses suggested that the data about insulin and glucose was not necessary in PAL Statistics, while the doctor would like to see this data in the system. The nurses mentioned that the data related to insulin, glucose and carbohydrates could be found in other existing systems already. A nurse indicated that data of food diary is more valuable for the dietician. However, the nurse mentioned that the function can be interesting as an activity for the child to keep a food diary for a certain amount of time. Then it might be interesting to see what the child has filled in the food diary. Both the nurses and doctor do not want the child to fill in the data manually. Furthermore, another nurse mentioned that it would be useful to include the standard settings of aspects that they have agreed on, such as the base stand and the carbohydrates ratio.

**Goals & Progress (PAL Control)** – Improving the visualisation of the 'goal tree' structure was not within the scope of this study. The additional visibility of an overview of actions and progression when the goal was selected in the 'goal tree' was perceived as very useful. In the previous version of PAL Control, healthcare professionals could not see which goals the child has been working on. In this prototype their need of having a clear overview of the progress of each goal of the child has been fulfilled. And also the option that the healthcare professional can add more goals based on their preferences was appreciated.

**Goals & Actions (in MyPAL through 'nurse view')** – Overall, the process of set goals and select actions was perceived as very positive by the participants. One healthcare professional stated: *'It is for the child a fun way to set goals and think about what he/she would like to learn. They really like the robot.'* Furthermore, healthcare professional especially appreciated the option to add their own actions if it is not in the list yet. One healthcare professional said: *'For example, when you know the child around 13 or 14 years smokes, you can add the action searching info what smoking does to your health for example .'*

**New functionality** – When asked if the participant would add more functionalities in this system, a participant suggested the functionality for children to ask questions towards healthcare professional when something comes into their mind, which they would like to talk about in the next appointment. A similar idea as in PAL inform, whereby parents can send their concerns to healthcare professional before the consult already.

#### *4.3.5 Doctor/management perspective*

The doctor did not have any prior experience with PAL Control and therefore a demonstration of the prototype was showed to him directly without conducting the think-aloud method and he did not fill in the SUS. From his experiences working with healthcare professional and in the management of the hospital he provided useful insights during the semi-structured interview. He mentioned that the hospital is doing a pilot project with a monitoring system called Gluconline, which is a virtual coach app for diabetes patients. Furthermore, they are experimenting with wearables. Therefore, he suggested that monitoring data should be uploaded through automatic sensors to make it easier for children. However, he mentioned that an important aspect whether new technologies are being used is the aspect whether it is reimbursed by health insurances. Moreover, he raised the question how data of EMR (Electronic Medical Record) and PAL data can be synchronised. Technically it might not be achievable according to him. Furthermore, he stated that if the information (e.g. medical items) in the 'profile' page has to be updated in two separate systems that it could lead to dangerous errors in case of serious conditions, such as peanut allergy. Last, he asked what the 'rewards' for children to adhere to the system are and he suggested some gamification aspects.

#### *4.3.6 General insights*

The lack of an automatic sensor that can upload the glucose and insulin values for children automatically was perceived as the biggest bottleneck according to all participants in this study. Furthermore, healthcare professionals would like to know if it is possible to synchronise EMR and PAL data and how this healthcare management tool could integrate in their current workflow and existing systems. In addition, it was found that if information cannot be synchronised, a safe and efficient way of information transfer needs to be reassured towards the healthcare professionals.

In general the healthcare professionals reacted positive towards the redesign of PAL Control. They perceived the role of the robot and its avatar very useful in motivating the child. Furthermore, they stated that the tablet could create an unconstrained atmosphere compared with the desktop and that it could influence the shared decision making process with child of setting goals and selecting actions positively. They appreciated the functionality of the child doing an assessment with the robot/avatar in order to help the healthcare professional determine which goals the child should be working on. In addition, they appreciated the colour use and pictograms. However, the progression page was perceived less positively than expected. The participants mentioned that they would like to see less graphs for the child and more gamification aspects.

Although participants were positive, they found it very difficult during the evaluation to rank their answer from 1 till 5 (with 1 strongly agree and 5 strongly disagree) to what extent their need has been fulfilled as described in table 1. They all mentioned that they needed

more time to really use the system in practice in order to understand these functionalities and to determine their answer. Furthermore, it remains unclear how many functionalities the healthcare professionals would like to have in PAL Control.

# 5. Discussion and conclusion

The research question this study sought to answer is: *'How can a healthcare management tool support healthcare professionals in guiding children with diabetes self-management involving a social actor (robot/avatar)?'*. To answer this question, a prototype of a healthcare management tool was developed and evaluated with end users (diabetes nurses) and an important stakeholder (diabetes doctor), following the sCE approach. The healthcare professional needs and system requirements, as described in table 1, and usability were the main points of evaluation. Overall, this prototype of a redesigned PAL Control was well perceived by the healthcare professionals and the findings demonstrated that there is potential for the proposed functionalities: an assessment with a robot or its avatar, set goals and selecting actions, create reports, an educational database for children and parents, monitoring solutions (MyPAL view, PAL Inform and PAL Statistics) and a progression page.

All healthcare professionals expressed that they see an added value in the robot/avatar and they especially liked the idea of the child playing an assessment with the robot, which can help them determine the gap in diabetes knowledge of children. Furthermore, healthcare professionals mentioned that this system has provided them support in making the consult with children and parents more meaningful due to the fact that they can understand their needs better on forehand through the progress page and the results of the assessment with the robot or its avatar. Also, healthcare professionals in this evaluation appreciated that the functionalities of setting goals and selecting actions with the child are run on the tablet. Next, they found the progress page useful to establish where the child has worked on and which topics need more attention, but they would like the progression page for the child to be more tailored to the child's age. Therefore, graphs are perhaps not suitable. However, they did like the usage of colours and pictograms.

During the evaluation, it was found that there were important differences in needs among the nurses and between the nurse and the doctor with regards to the number of functionalities and the perceived usefulness of certain data in the system. Many important individual differences need to be taken into consideration. Moreover, we need to discuss more about the role of PAL, is it an addition or will it replace the existing systems that healthcare professionals already use and how does this influence the current workflow of healthcare professionals? Will PAL Control be used after or before the normal consult or replacing the consult?

An ethical aspect within this prototype is how much information you can show the healthcare professional without invading the privacy of the child. Perhaps the child wants the healthcare professional to know what he/she has filled in. In the functionality 'PAL statistics' the texts related to emotions can be filtered out for the healthcare professional to read in order to get a better understanding how the child was feeling at that moment. Furthermore, the function 'MyPAL view' allows the healthcare professional to see the interface of MyPAL, which contains data filled in by the child. Although these two functionalities were perceived as useful by the healthcare professional, it should be taken into consideration that the child should not get the feeling of 'big brother is watching'.

The evaluation results together with the data using the 'thinking aloud method' and SUS score were used to iterate specifications of the functionalities and provided guidance in the improvement of the prototype. These improvements are:

**Recommendation system** – The functionality of the database with educational material was perceived as useful, but a critical concern was that this database should be kept organised in a clear and user friendly overview. A possible redesign of this functionality is to add a recommendation system, whereby healthcare professionals and children can give a rating of the material after they have seen it. Healthcare professionals could also add their keywords when they upload their own educational material. This could make the process of finding suitable educational information for the child more easily.

**Recording messages** – Based on the suggestion of one healthcare professional about the new functionality of giving children the option to send questions to healthcare professionals, a possible solution is that the child can record a message to the robot. For example, the child has played the quiz and does not understand why the answer he picked was incorrect. He would like to ask the healthcare professional next time about it. In order to not forget this question, the child can already send his question to healthcare professional through the robot, e.g. by clicking a button with 'message to healthcare professional' the voice recorder starts. In other words, the robot functions as a messenger from the child to the healthcare professional. During the consult healthcare professional and child can listen to the recorded questions together and discuss them, followed by optionally adjusting the goals and actions.

Finally, healthcare professionals stated that they would like this prototype to be built in a real system in order to test for a longer period of time and during multiple pilot consults in a setting with children, parents and the robot. Therefore, evaluations for a longer period of time is needed in order to validate if the needs are completely fulfilled. Nonetheless, useful suggestions were found during the evaluation of the prototype and provided important pointers in besides the development of PAL Control, also in PAL Inform and MyPAL. The sCE approach supports the credibility of the findings and ongoing reflective practice enhances the methodological thoroughness. End-users got an opportunity to express their needs in an early stage, which provided a strong foundation for the development of the prototype. Based on these preliminary results, we expect that this healthcare management tool can support the healthcare professionals in the assessment of children's T1DM knowledge, goals and development. In addition, the evaluation results of this healthcare management tool prototype are also relevant for healthcare professionals guiding children with other illnesses requiring self-management such as asthma or issues that negatively influence children's well-being such as bullying.

In summary, our results suggest that a combination of an assessment with robot or its avatar, setting goals, selecting actions and the progression page, is a suitable and effective approach to healthcare professionals in guiding children with diabetes self-management.

## 5.1 Limitations

Mostly, qualitative data were collected from six individuals, which makes the findings difficult to be generalised to a larger population. However, the qualitative data collected in this study provided useful and detailed information. Also, due to a limitation in time during the evaluation the thinking aloud method was sometimes partly replaced with a demonstration followed by a discussion and a semi-structured interview. Nonetheless, a range of confirming insights seemed to be captured.

## 5.2 Future work

Although the study found evidence of preliminary positive effects of the new functionalities in the prototype of PAL Control, further research by developing a real system based on the core functions of this prototype that allow healthcare professional to experience working with the tool for a longer period of time in a real pilot setting, are necessary to determine the effects. This will be an important step in the process of establishing a set of guidelines towards creating a useful healthcare management tool for healthcare professional. Also, needs of parents and children with regards to the role of healthcare professional should be elicited through further research. Furthermore, the content of the assessment (quiz, goals and actions) and the 'goal tree' structure should be established together with diabetes experts and reviewed by healthcare professional. Next, this project PAL could elaborate with new technologies, such as wearables that can registrate values automatically and avoid that children have to complete it manually. More research is needed to investigate possible options that allow this healthcare management tool to integrate in the existing systems (e.g. electronic health record and other monitoring programs that the

healthcare professional are already using).

Most importantly, the concepts as proposed in this study aims to support children under guidance of a healthcare professional and it should therefore be evaluated in a setting with children to understand how healthcare professionals interact with children, while using PAL Control. Children should be motivated and engaged in using and maintaining the application for it to be a success. Therefore, another future research aspect is how can the healthcare professional/robot reward the child for achieving the goals in order to continuously motivate the child. Finally, more research is needed to study how the PAL avatar should interact with the child in a meaningful way in order to motivate children in achieving their personal goals as set together with the healthcare professional.

### 5.3 Conclusion

This study shows how a healthcare management tool, PAL Control, can help healthcare professionals guiding children with diabetes. This study focuses on the extent to which this tool fulfills the needs of healthcare professionals and the perceived usability. The results showed an overall positive increase in perceived usability compared with the previous PAL Control version. Healthcare professionals appreciated the usage of colours and pictograms. Overall, the evaluation outcomes are positive and represent a good basis for further development. Our results suggest that a combination of an assessment with a robot or its avatar, setting goals, selecting actions and the progression page, is a suitable and effective approach to healthcare professionals in guiding children with diabetes self-management. Potential improvements in the prototype of a redesign of PAL Control were identified.

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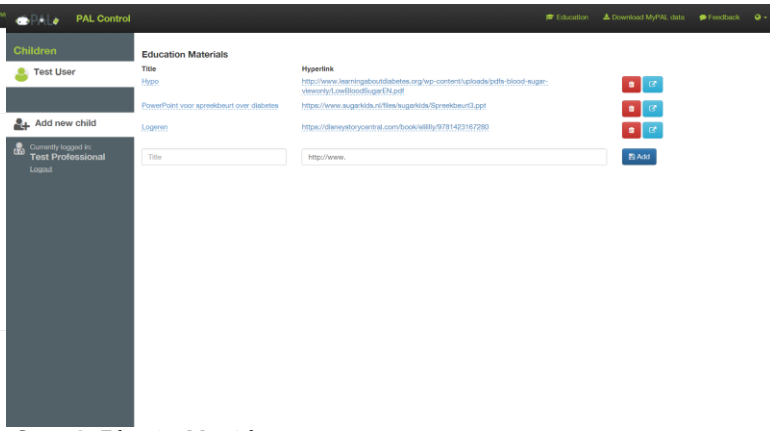
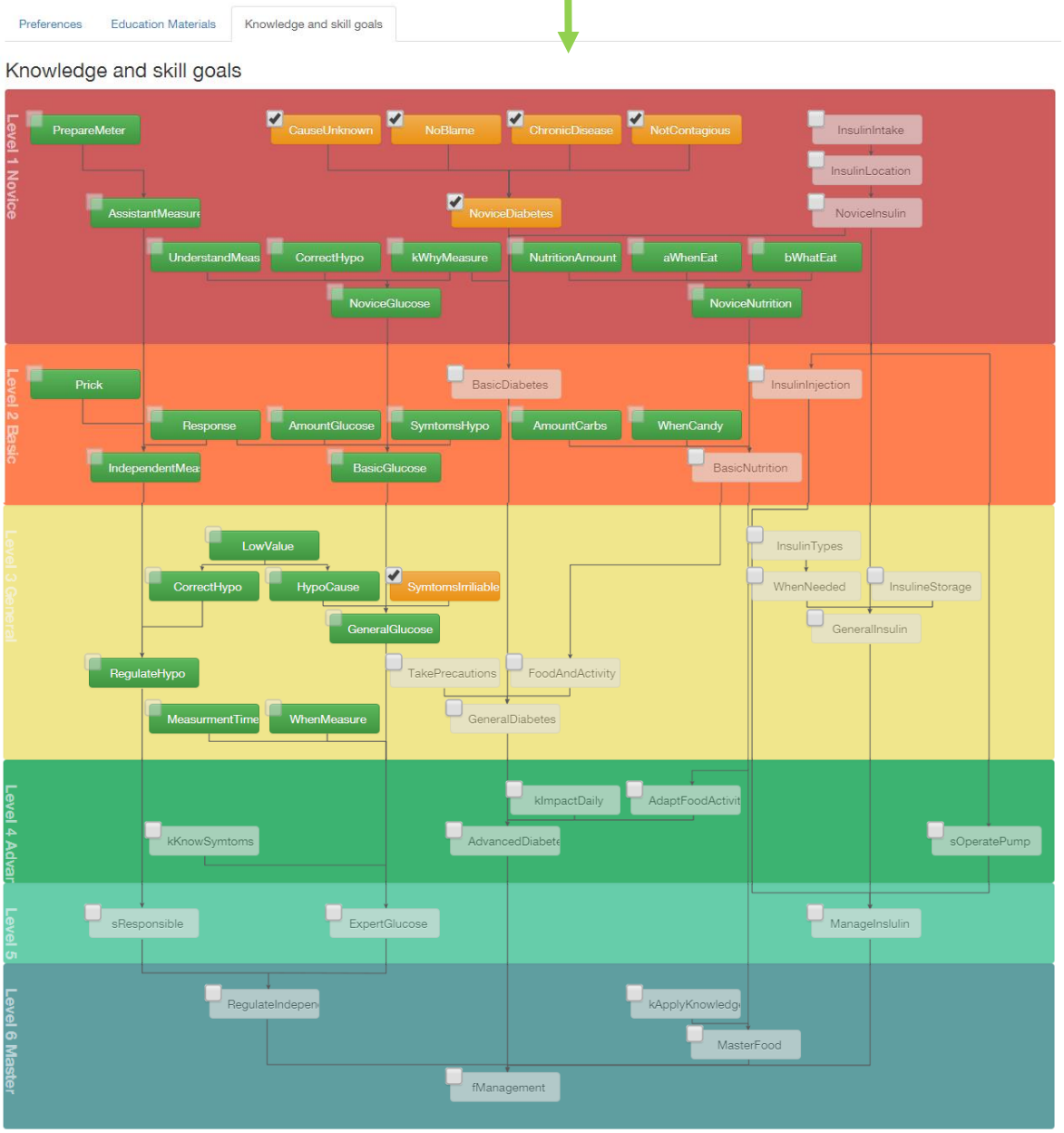
# Appendix A: Current state of PAL Control (version 17-12-16)


Screen 1. Select Child (left side); Profile Child (at the top);
'Goals Tree' structure (see image below for a close-up)




Screen 2 . Education Material



# Appendix B: Storyboards

The storyboards can also be found on the link: [www.tinyurl.com/palcontrol](www.tinyurl.com/palcontrol)


Pal Control on desktop

Robot Charlie

Robot-Avatar on tablet

Healthcare Professional (HCP)*

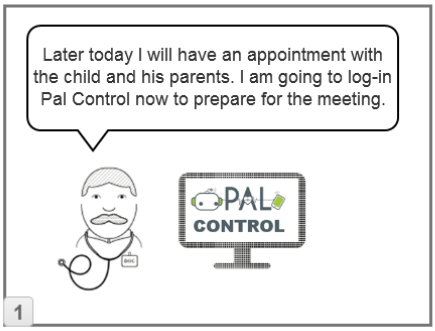
*This study focuses on the role of a diabetes nurse.

Child**

**Child is between 7-14 years old.

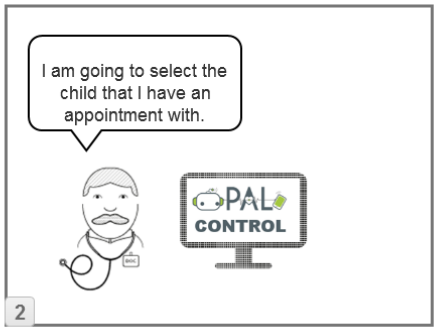
Parents

## 1. At Hospital - Before the appointment (Optional for HCP to prepare for consult)



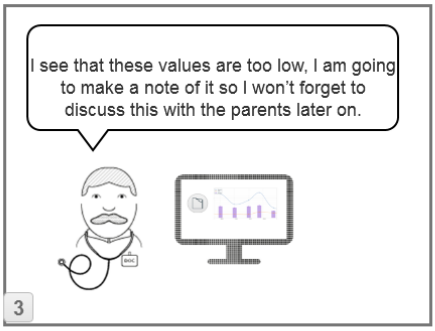

**Login Pal Control Desktop**

HCP login Pal Control by filling in his username and password.



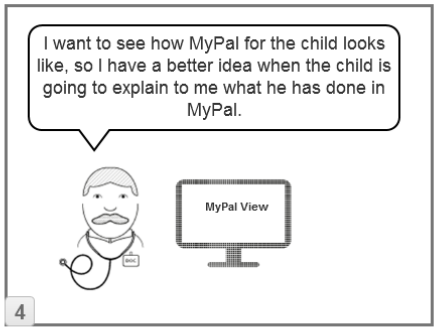

**Select Child**

HCP selects the child that he is going to have an appointment with. After selecting, the names of other children will not be visible to the child/parents during the consult.



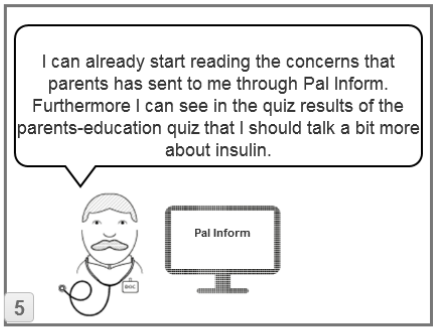

**Monitor - MyPal Statistics**

(Optional) HCP is looking at the values and make some notes by clicking on the 'note icon'. He wants to use these notes to discuss with the parents later on during the appointment.



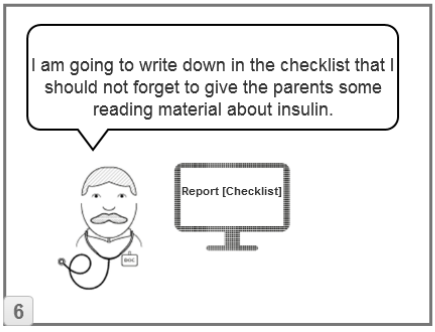

**Monitor - MyPal View**

HCP can see how MyPal looks like exactly by going to Pal Control Monitor section (My Pal View). This shows the same interface as what the child has in real-time.



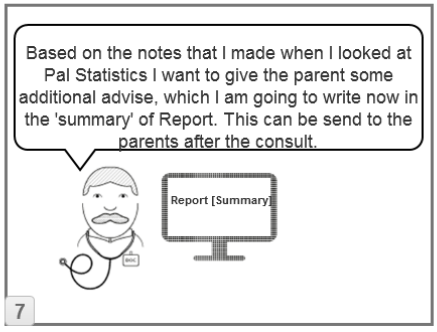

**Monitor - Pal Inform**

HCP reads the concerns that parents has sent him. This helps him to understand the needs of parents better and it can save time during the consult. This is not a direct real time chat. It is an easy way for parents to write down their concerns and it gives HCP a nice overview.



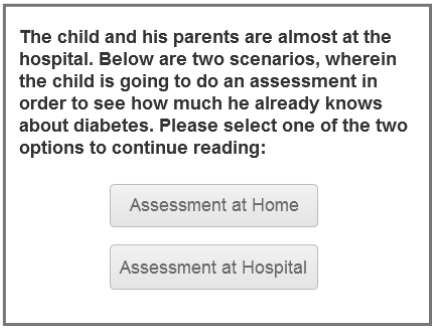

**Report [Checklist]**

In the 'report' section of Pal Control there is an option for a checklist that can help as a reminder.

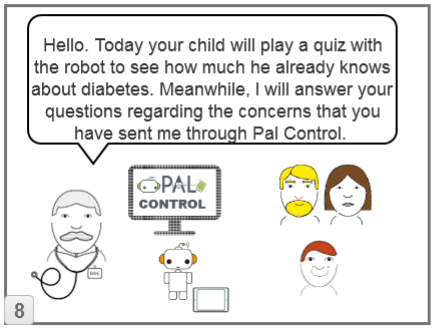



**Report [Summary]**

The HCP can already start writing some topics in the 'summary' section of report that can be useful as a guideline during the consult with the parents.



## 2a. At Hospital - Assessment  Child with Robot

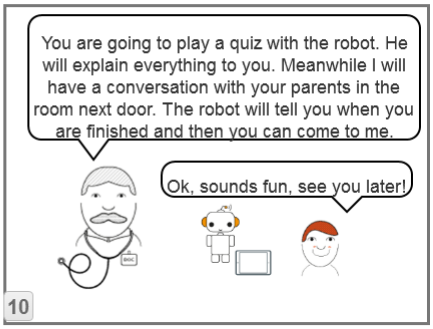



**Introduction**

HCP introduces robot and avatar to child and parents.


**HCP sign in Nurse View**

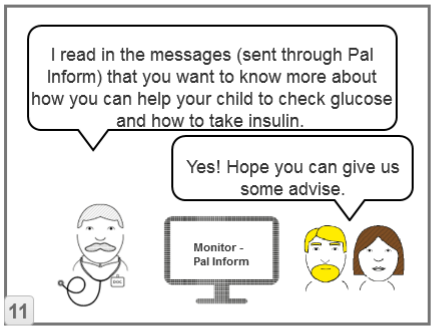
'Sign in Nurse View' is for the HCP. When they sign in they have access to start the assessment for the child, set goals, select actions and edit the progression of the child.




**HCP explains assessment**

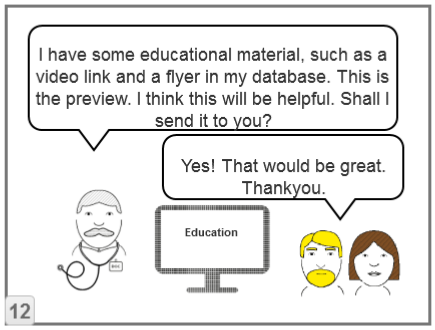
HCP explains to the child that he is going to play a quiz with the robot. The goal is that the child will experience more fun by playing the quiz with the robot compared with the HCP asking him questions.

### Meanwhile...



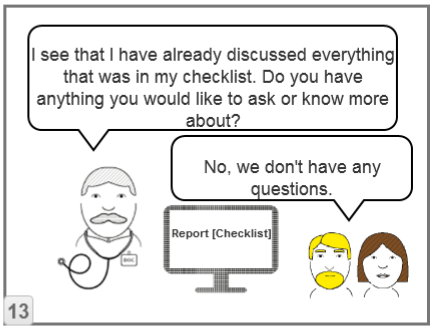

**Monitor - Pal Inform**

HCP discusses the concerns that the parents have. HCP is already prepared, because he has already read it through Pal Inform.




**Education - Parent**

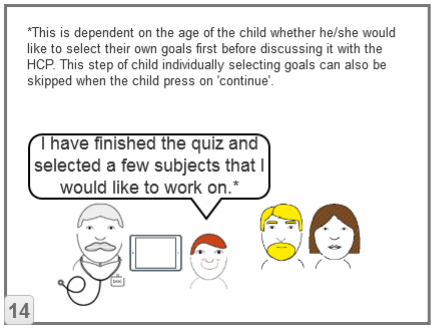
HCP selects the educational material for the parents and press 'save', which will go as an attachment in the 'report' section later on.




**Report [Checklist/Notes]**

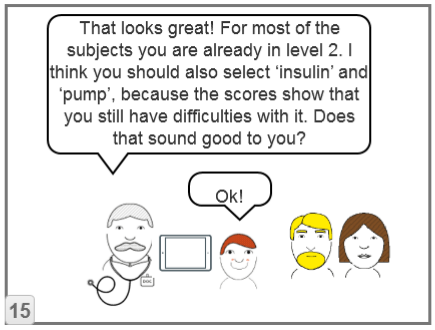
HCP looks at his checklist and notes to see if he has discussed everything.

### HCP discusses together with child about goals and actions on the tablet (nurse view)



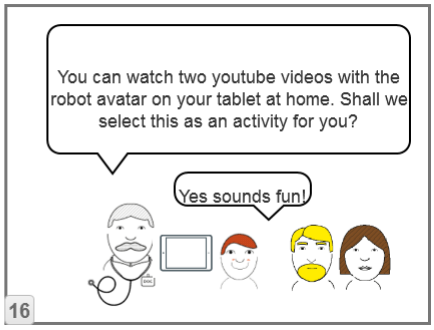

**Child shows the subject that he has selected**

The child and HCP will continue discussing the goals and actions on the tablet (instead of desktop). The reason is to improve the HCP-child interaction and by using the device (tablet) of the child you will involve them more in the decision process of selecting goals and actions.



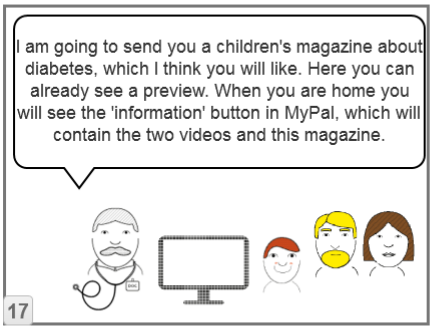

**Set Goals**

HCP and child will look together on the tablet and discuss about what the child wants to learn and what he would like to do as an activity to reach his goals.




**Select Actions**

These activities are already in MyPal, the HCP only has to select them and personalise them (e.g. by defining the amount of videos that the child is going to watch). By activating the actions that consist of watching a video, the video will appear in MyPal 'Information' button automatically.

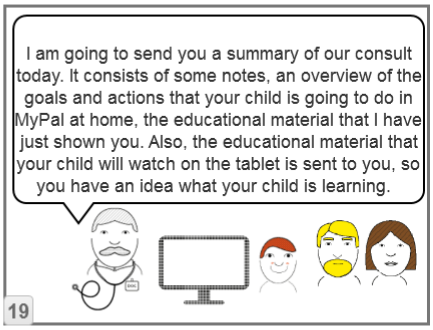



**Education - Child**

HCP can also add more 'actions' in it, in case he wants him to do another activity, such as reading a magazine that is not in the database yet.


**Progress**

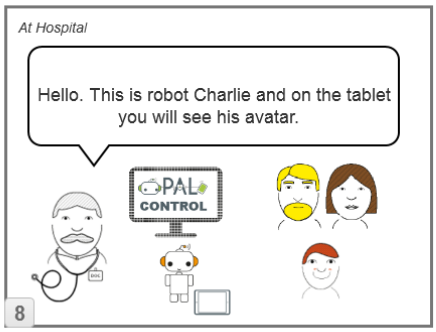
HCP explains 'progress' button in MyPal.



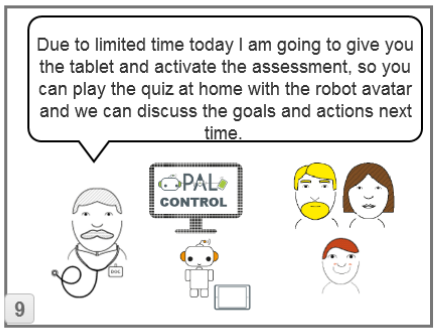

**Report [Send E-mail]**

HCP explains what he is going to send the parents. The parents can have a look at this summary again if they forgot what the HCP has told them. Also, they have an overview of the learning goals and actions of their child.

## 2b. Assessment Child with Robot-Avatar on tablet




**HCP introduces robot and robot-avatar.**




**HCP activates assessment**

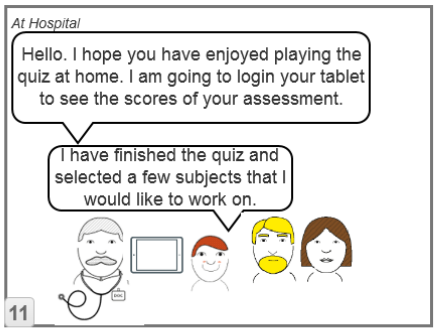
HCP wants the child to play the assessment at home on the tablet. He can activate the assessment easily by pressing on a button in Monitor (MyPal View) .

### Child plays assessment at home


**Assessment at home**

Robot-avatar explains to child how to start the assessment.

## Next appointment: HCP discusses together with child about goals and actions on the tablet (nurse view)

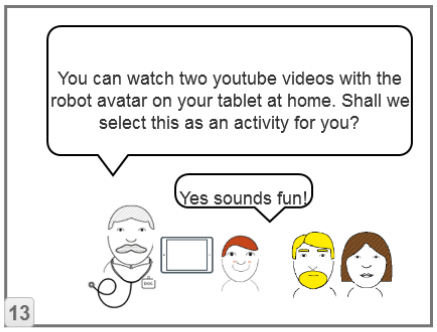



**Child shows the subject that he has selected**

The child and HCP will continue discussing the goals and actions on the tablet (instead of desktop). The reason is to improve the HCP-child interaction and by using the device (tablet) of the child you will involve them more in the decision process of selecting goals and actions.

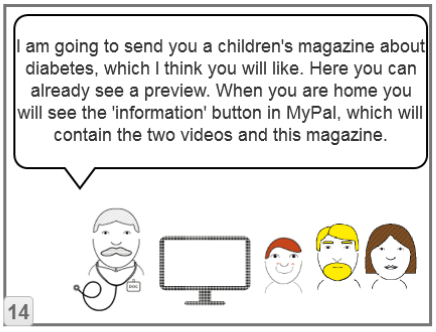

**Set Goals**

HCP and child look together in MyPal and discuss about what he wants to learn and what he would like to do as an activity to reach his goals.



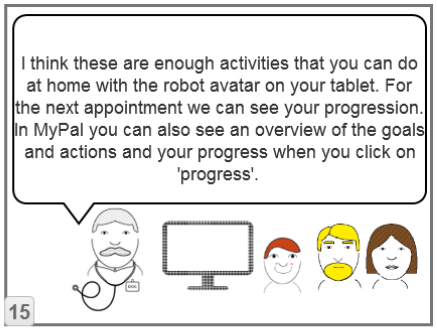

**Select Actions**

These activities are already in MyPal, the HCP only has to select them and personalise them (e.g. by defining the amount of videos that the child is going to watch). By activating the actions that consist of watching a video, the video will appear in MyPal 'Information' button.




**Education - Child**

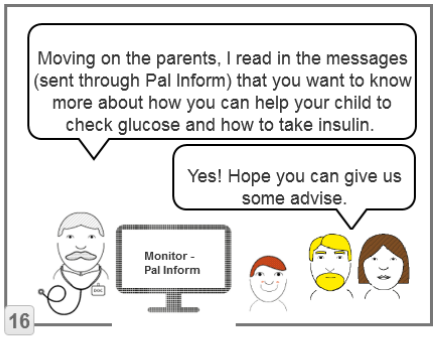
HCP can also add more 'actions' in it, in case he wants him to do another activity, such as reading a magazine that is not in the database yet.




**Progress**

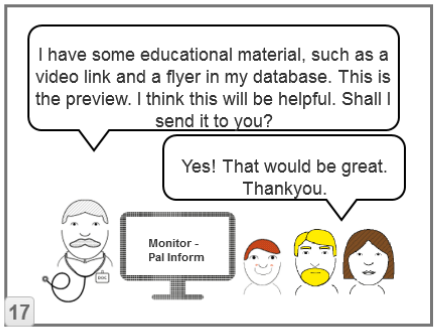
HCP explains 'progress' button in MyPal.

### HCP discusses with parents



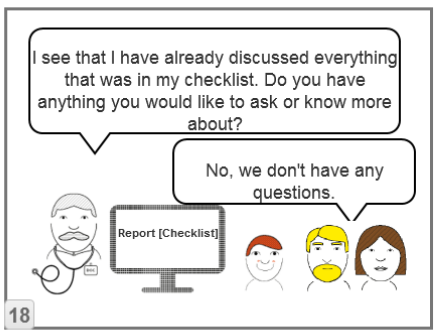

**Monitor - Pal Inform**

HCP discuss the concerns that the parents have. HCP is already prepared, because he has already read it through Monitor - Pal Inform.



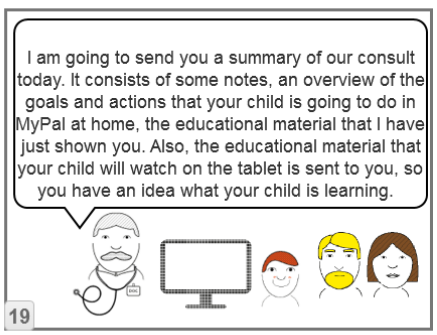

**Education - Parent**

HCP selects the educational material for the parents and press 'save', which will go as an attachment in the 'report' section later on.




**Report [Checklist/Notes]**

HCP looks at his checklist and notes to see if he has discussed everything.




**Report [Send E-mail]**

HCP explains what he is going to send the parents. The parents can have a look at this summary again if they forgot what the HCP has told them. Also, they have an overview of the learning goals and actions of their child.

### 3. Second appointment


**Progress**

HCP and child look together at the progress through 'nurse view' on the tablet.

**Set Goals**

HCP and child look together in MyPal and discuss about what he wants to learn and what he would like to do as an activity to reach his goals.

**Select Actions**

HCP can adjust the actions based on the actions that he has selected last time or add new actions.

The storyboard above shows the beginning of how the second appointment (after the child has worked on the actions at home) might look like in the ideal situation. Only the first three main features are visualised. The rest of the storyboard repeat itself (see storyboard 1, 2a/2b).

## Appendix C: Use Cases

The use cases below are presented as the situation most likely going to occur when all goes well. They are focused on the perspective of the healthcare professional, which is abbreviated as HCP for convenience.

**Use Case: Monitor –MyPAL View**

Goal: HCP can get access into MyPAL in order to understand the activities that the child is doing in MyPAL.

Actor: PAL Control, HCP

Pre Conditions: HCP has experience using PAL Control.

Post Conditions: HCP understands what the interface of MyPAL looks like for the child.

Action Sequences:

1. HCP wants to see how the activities 'quiz' and 'filling in diary' looks like for the child.
2. HCP log in PAL Control
3. HCP select the tab '*monitoring – MyPAL View'* in the menu
4. HCP sees the same interface of MyPAL that is visible for the children
5. HCP can have a quick look at how the functionalities 'diary' and 'quiz' works for the child.

Requirements:

- PAL Control shall provide a functionality whereby the HCP can see how MyPAL looks like for the child anytime.

**Use Case: Monitor – MyPAL Statistics**

Goal: HCP gets insights about the data of the child regarding his/her activities in MyPAL and can make notes about the data.

Actor: HCP, PAL Control

Pre Conditions: Child has used the functionalities 'quiz' and 'diary' in MyPAL.

Post Conditions: HCP understands the needs of the child better by looking at the data.

Action Sequences:

1. HCP log in PAL Control
2. HCP selects the tab '*monitoring – MyPAL Statistics'* in the menu
3. HCP sees an overview of data, which elecit insights such as child-user's progression on PAL-objectives, emotion, daily activities and system usage.
4. HCP can type notes that she wants to discuss about later on during the meeting . These notes will appear in 'report'. (→ see use case reporT).

Requirements:

- PAL Control shall provide an overview of child-user's progression on PAL-objectives, emotion, daily activities and system usage, whereby important/critical situations can be filtered.

**Use Case: Monitor – PAL Inform**

Goal: HCP can get insights of the knowledge and concerns of parents.

Actor: HCP, PAL Control, Parents, PAL Inform

Pre Conditions: Parents has experience using PAL Inform and HCP has experience using PAL Control

Post Conditions: Parents can tell their needs before hand and HCP can prepare themselves before the consult by reading these needs.

Action Sequences:

1. HCP selects the tab '*monitoring – PAL Inform'*.
2. An overview of concerns sent by parents will appear.
3. Also, a quizscore of each topic related with diabetes knowledge (played by the parents) will appear.
4. HCP can use these information as guidance during the consult to determine how she can help the parents (e.g. give more information → see usecase education).

Requirements:

- PAL Control shall provide an overview of concerns that the parents have send.
- PAL Control shall provide an educational quiz for parents and an overview of the results of the quiz for the HCP.

**Use Case: Monitor – Goals & Progression**

Goal: HCP gets insights about the goals of the child and his/her progression

Actor: HCP, PAL Control

Pre Conditions: Child is working on the 'actions' and when these are fulfilled, the goal is reached.

Post Conditions: HCP can see which goal the child has been working on and how much time he needed.

Action Sequences:

1. HCP selects the tab '*goals*' in the menu
2. In the 'goals' section an overview of actions and a clear description of the goal will appear.
3. HCP can sees the child's progression (progress bar) in fulfilling each action, which corresponds to a goal.
4. HCP can add more goals by selecting from the list of optional goals.

Requirements:

- PAL Control shall provide an overview of goals, a clear description, ability to add more goals and the progression of child's performances.

**Use Case: Report**

Goal: A guideline tool of topics where HCP can talk about during the consult with parents/child and a functionalitiy to send a summary of notes, goals and corresponding actions to the parents.

Actor: PAL Control, HCP and parents

Pre Conditions: Goals and actions are selected.

Post Conditions: HCP has an overview of notes, which they can send to parents if they want. Parents can receive a summary of notes, goals & actions.

Action Sequences:

1. The notes that the HCP typed in the PAL statistics page will appear again in the section 'report'.
2. HCP can use these notes to write an advise for parents.
3. HCP can send these notes together with an overview of goals & actions of the child to the parents.
4. If any education material has been selected in 'education' section, these reading material will be sent as an attachment as well.
5. Parents can read this overview again at home if they want.

Requirements:

- PAL Control shall provide an option to send a summary of notes to the parents, an overview of the selected goals and the corresponding actions in order to give the parents a better understanding of what their child is learning and the educational materials as an attachment (if any material was selected in 'education').

**Use Case: Education [parents]**

Goal: HCP can select educational material for parents.

Actor: HCP, PAL Control, PAL Inform and parents.

Pre Conditions: HCP has experience working with PAL Control.

Post Conditions: Parents receive educational material that can fulfil their needs.

Action Sequences:

1. HCP reads the concerns that are sent by parents through PAL Inform before the consult or during the consult together with parents.
2. HCP selects educational material from the database and discuss together with parents if this information can be useful.
3. HCP sends this information as an attachment, which will appear in 'report' as an overview of information that will be sent to parents.
4. HCP can also add their own educational material in the database and share it with other HCPs.
5. Parents can read this material at home.

Requirements:

- PAL Control shall provide a portfolio of educational materials (for parents) from which the HCP can select/add and send as an attachment (under 'report').

**Use Case: Progress for child**

Goal: Child has a clear overview of the progression of achieving goals in MyPAL.

Actor: MyPAL, PAL Avatar, Child

Pre Conditions: Child has experience using MyPAL.

Post Conditions: Child sees his own progression and understands what his actions are in order to achieve a goal.

Action Sequences:

1. PAL avatar explains child that he ca n finds an overview of his actions and goals when he clicks on the 'progress' pictogram.
2. Furthermore, the progress of each action is visualised in a progressbar.
3. Child can see his progression and understand which actions he still has to complete in order to achieve the goal.

Requirements:

- PAL Control shall provide an overview of child-user's progression on goals and achievements for the HCP.
- PAL Control shall provide an overview of child-user's progression on goals and achievements in a way that motivate the child to continue achieving the goals.

**Use Case: Assessment Hospital/Home**

Goal: A fun assessment in order to test the diabetes knowledge of the child in order to select the appropriate goals for her/him.

Actor: HCP, child, PAl Control, PAL avatar

Pre Conditions: Child has experience with MyPAL

Post Conditions: HCP can made an estimation which goals and corresponding actions to select for the child. Child understands why he has to do these 'actions' and understand where these 'actions' came from.

Action Sequences:

Hospital

1. HCP explains child that he is going to play a game with the robot.
2. Depending on the age HCP can sit next to the child and help with the introduction questions first.
3. Child plays the game and follow the instructions given by the robot.
4. After finishing the quiz, the robot shows the child an overview of scores for each topic, which is represented by a pictogram.
5. Robot instructs the child to select the pictograms he would like to work on as a goal.
6. Child selects a few pictograms.
7. Robot instructs the child to show these pictograms to the HCP and discuss together.

Alternative Sequence:

6. Child does not select pictograms.
7. Robot suggests child to select a few pictograms based on the scores of the assessment. Topics where the child has a low score will be suggested by the robot.
8. If child still does not select pictograms, the robot will instruct the child to skip this step and discuss the goals with HCP.

Home

1. HCP explains child that he is going to play a quiz with PAL avatar on the tablet and that he can do that in his own time at home. At the next consult they will discuss together about the goals and actions.
2. HCP activate the assessment through 'MyPAL View' by clicking on the button 'activate assessment'.
3. Child follows the instructions given by the PAL avatar and plays the quiz.
4. PAL avatar shows the child an overview of scores for each topic, which is represented by a pictogram.
5. PAL avatar motivates the child to select a few pictograms or that he can skip this step and discuss it next time at the hospital with the HCP.

Requirements:

- PAL Robot/ PAL avatar shall motivate the children in finishing the assessment and praise children in ways that acknowledge their efforts.

**Use Case: Education [children]**

Goal: HCP can select educational material for children.

Actor: HCP, PAL Control, MyPAL, child, PAL Avatar

Pre Conditions: HCP and child has experience with PAL.

Post Conditions: Child watch the educational material together with PAL avatar.

Action Sequences:

After HCP and child decide to select actions related to watching educational material in order to achieve a goal, educational material will appear in MyPAL under the section 'information'.

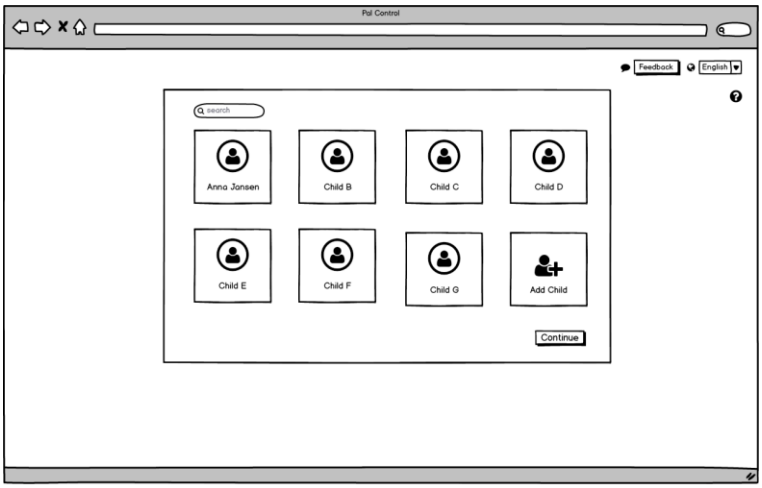
Alternative Sequence:

1. HCP wants to add educational material that he/she finds suitable for the child, which is not in the database yet.
2. HCP goes to the section 'education' in the menu of PAL Control.
3. HCP upload the material and click on 'save', which will transfer this material to MyPAL under the section 'information'.
4. PAL avatar explains to child that HCP has sent e.g. a Youtube Video to watch together and after watching it, one of the 'action' is fulfilled in order to achieve the goal.

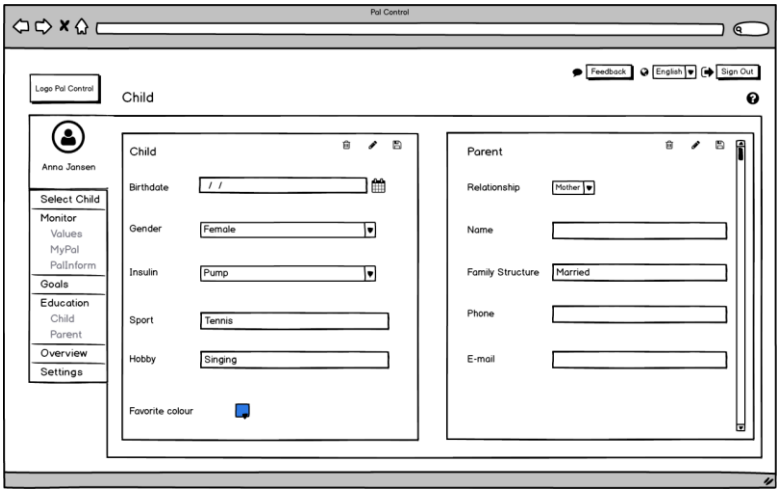
Requirements:

- PAL Control shall provide a portfolio of educational materials (for children) from which the HCP can select/add, whereby PAL Actor will motivate the child to read these materials in MyPAL.

## Appendix D: Mockups

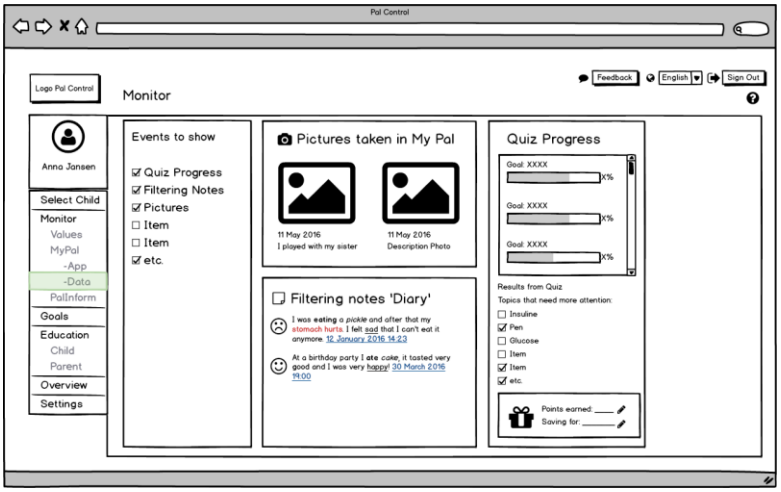



1. Overview Children



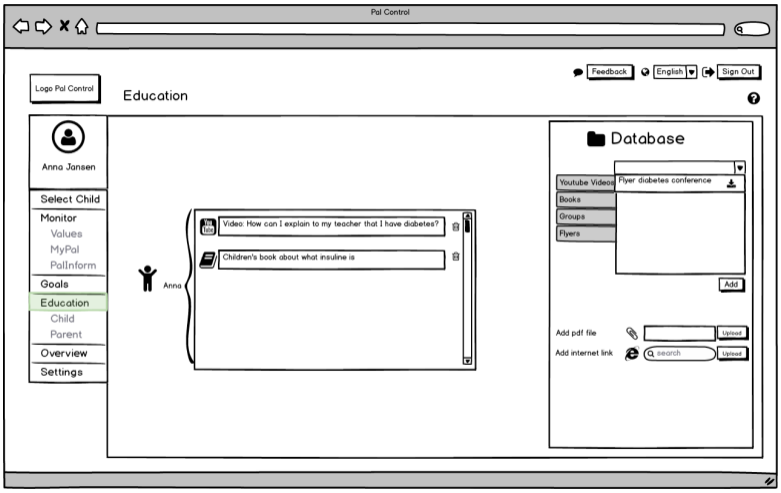

2. Profile Child


3. MyPAL Values Statistics

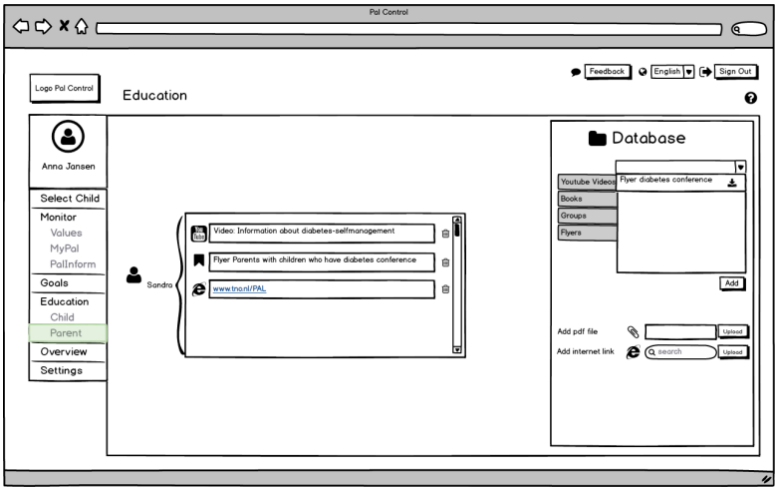



4. MyPAL Diary & Quiz Statistics

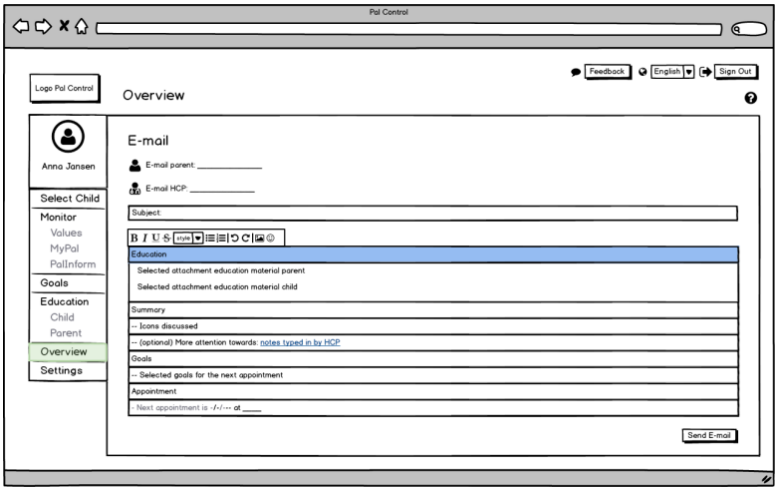

5. MyPAL View



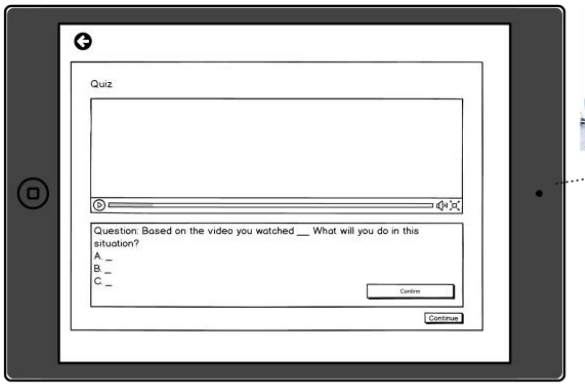

6. Select educational material for child

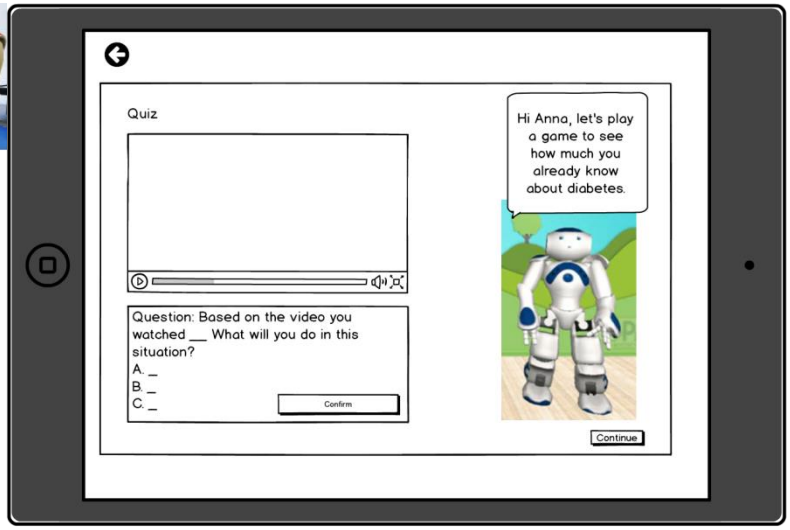



7. Select educational material for parent




8. Report




9. Assessment with PAL Robot in hospital

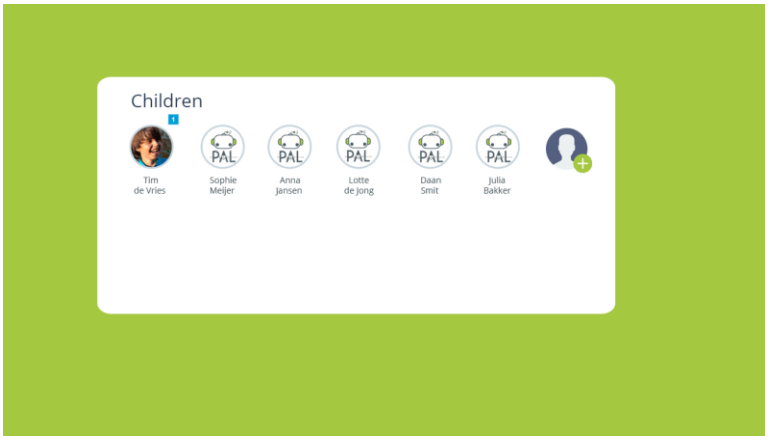
10. Assessment with PAL avatar at home

## Appendix E: Prototype

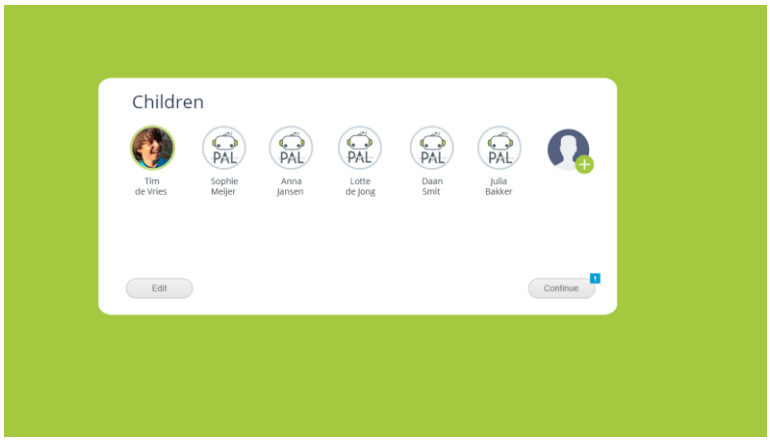
In the images below are print screens of the prototype. The blue square means that that this element is clickable. The link to experience the clickable prototype can be found here: [www.tinyurl.com/palcontrol](www.tinyurl.com/palcontrol)

### Scenario: Pal Control Desktop

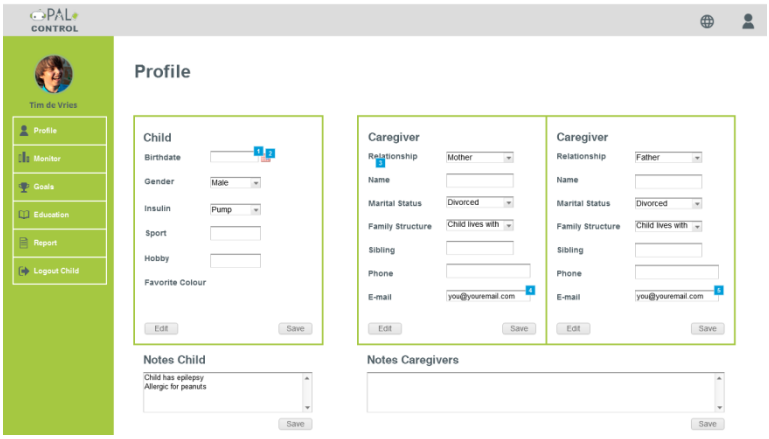

Screen 1. Login Pal Control Desktop



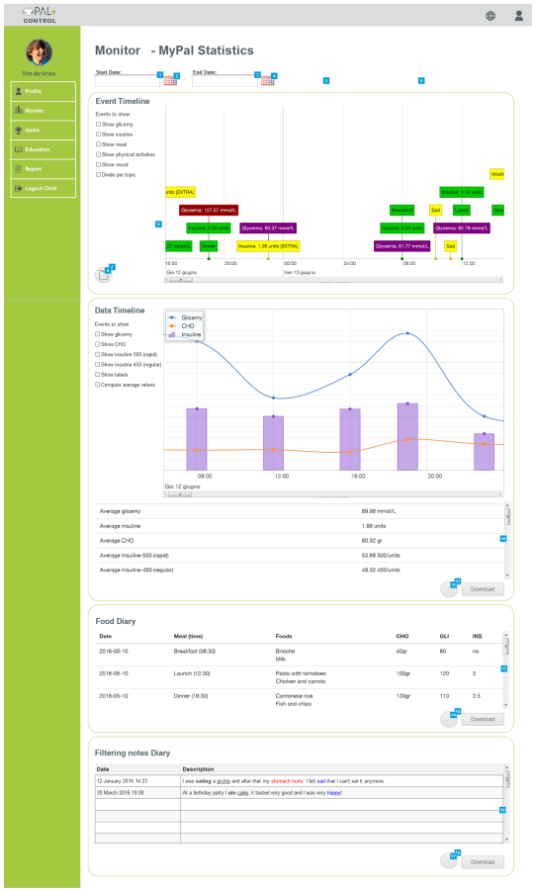

Screen 2. Overview Children



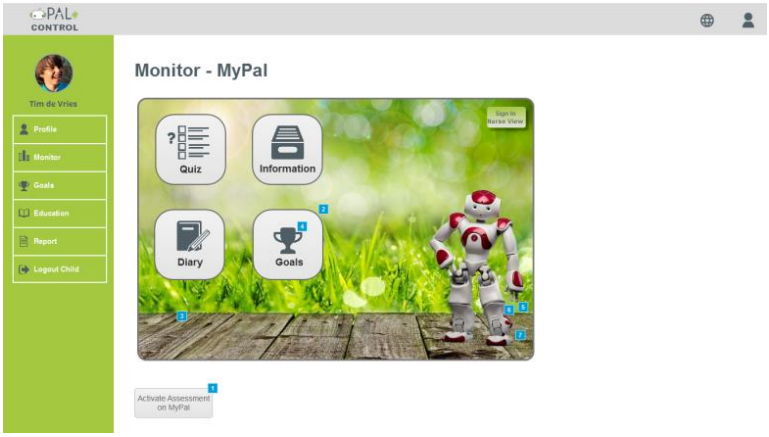

Screen 3. Select Child




Screen 4. Profile Child



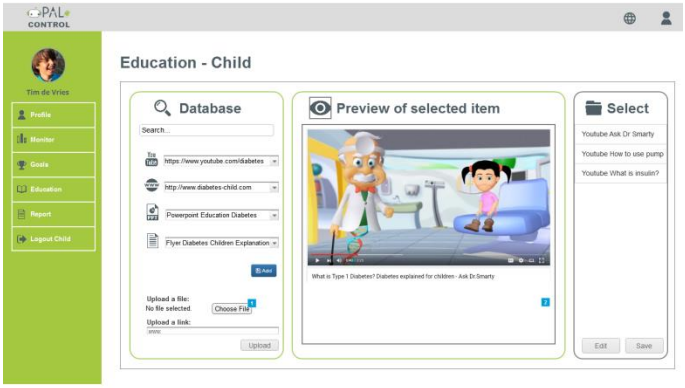

Screen 5.
MyPAL Statistics



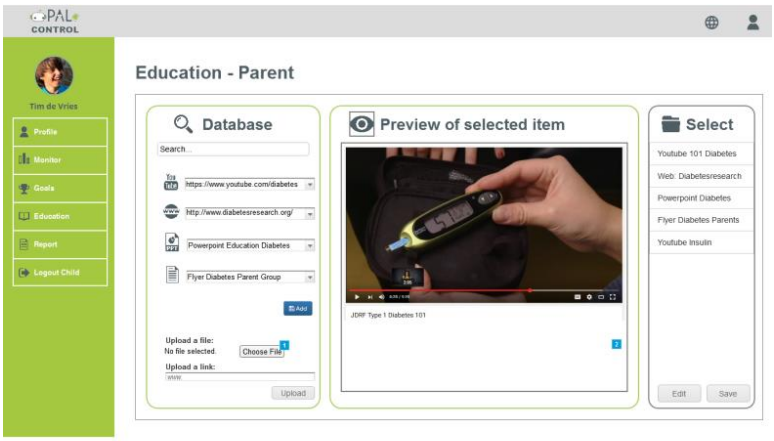

Screen 6. MyPAL View


Screen 7. PAL Inform

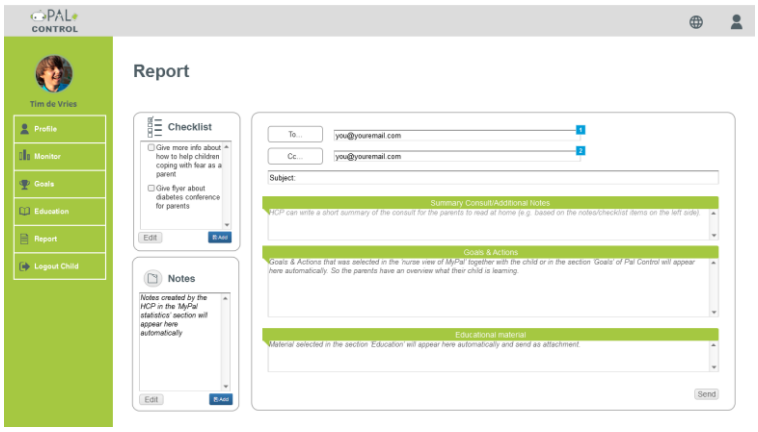

Screen 8. Goals




Screen 9. Education - Child

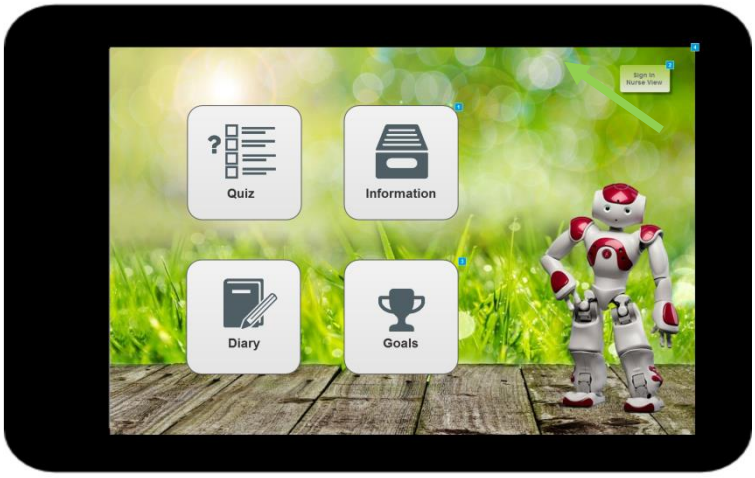



Screen 10. Education - Parent

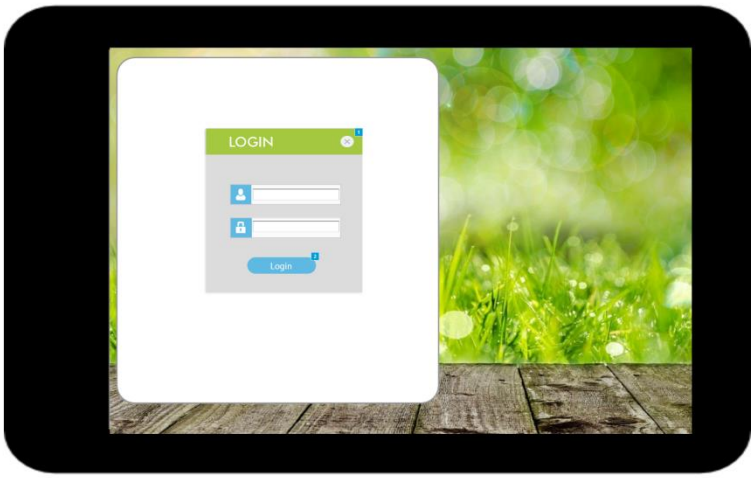



Screen 11. Report

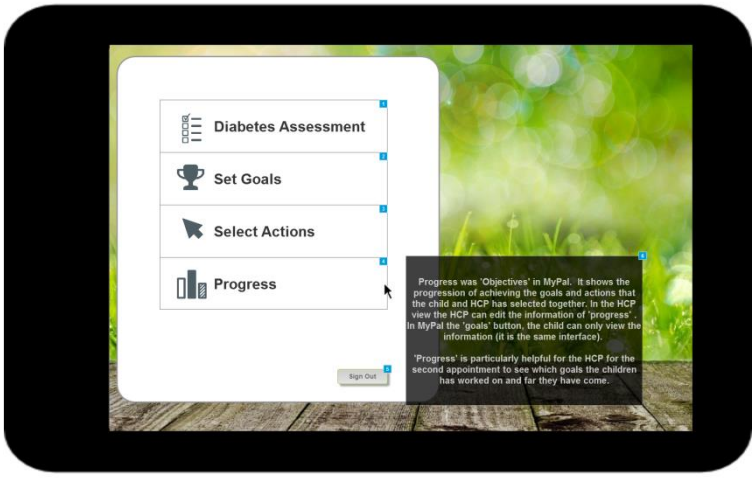
## Scenario: Assessment at Hospital [Child and PAL robot]



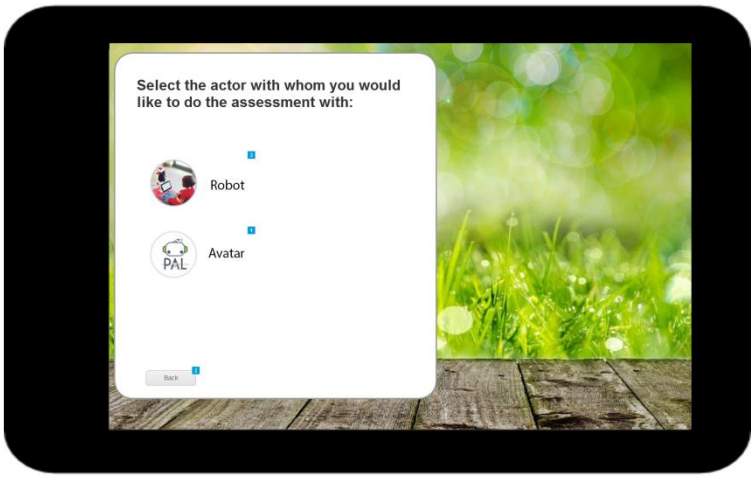

Screen 12. Home screen MyPAL Child with 'sign in button (right corner).



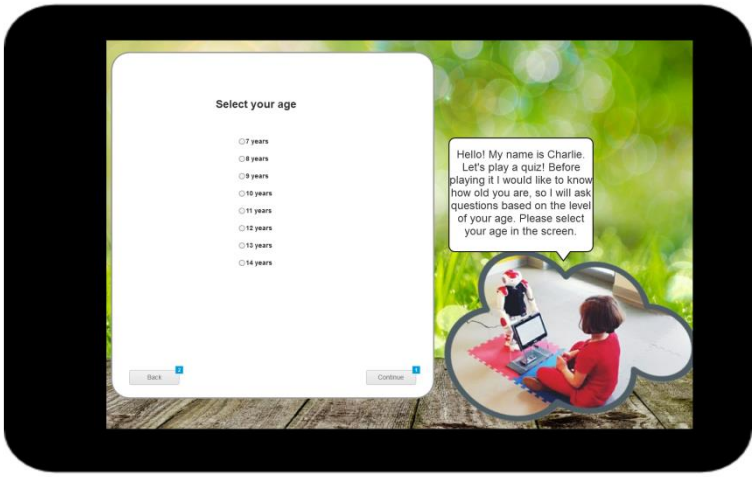

Screen 13. Sign In Nurse View



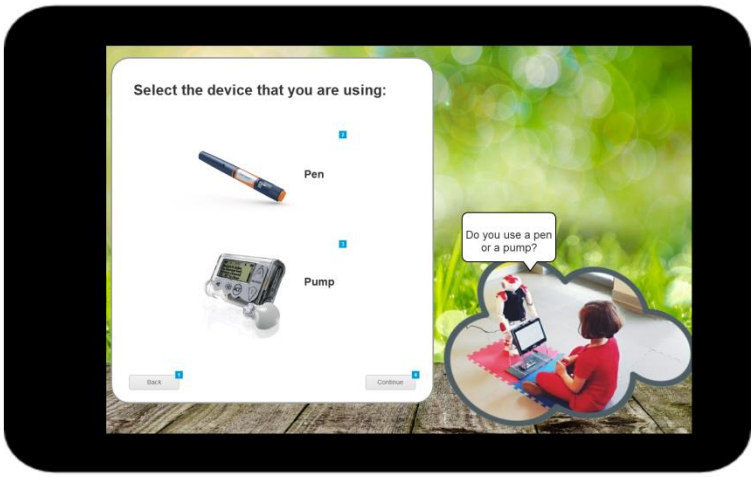

Screen 14. Home screen Nurse View



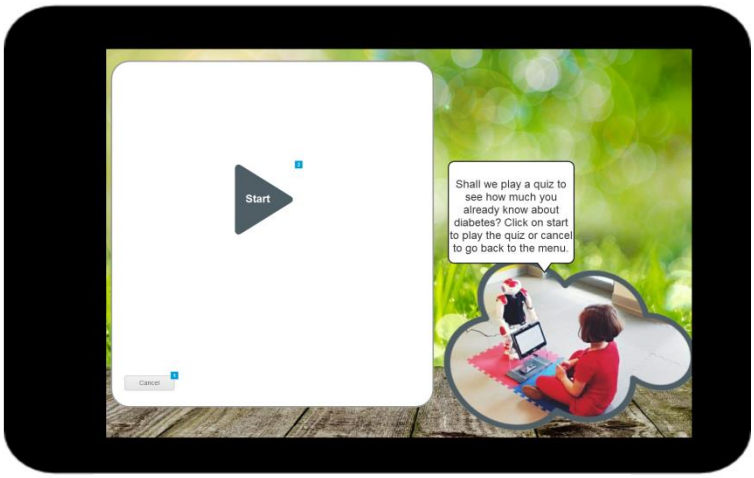

Screen15. Select Actor



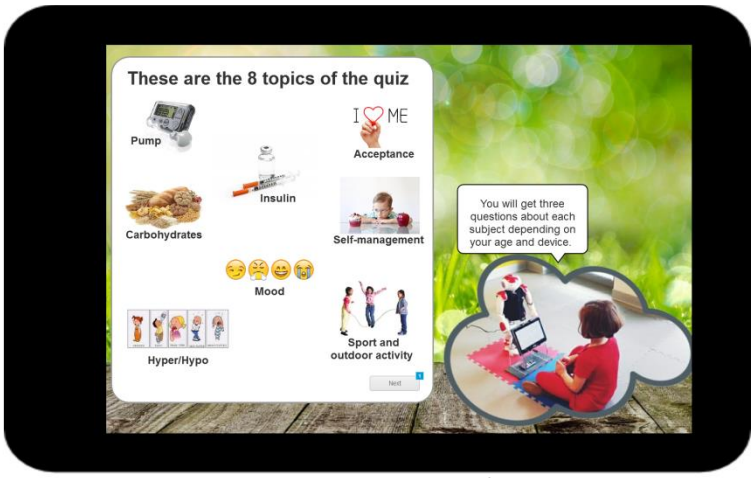

Screen 16. Robot asks child to select his/her age



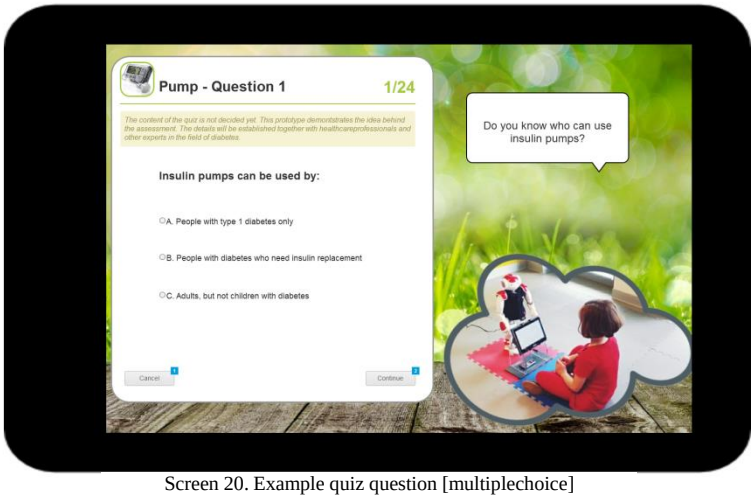

Screen 17. Robot asks child to select his/her device (pump/pen).



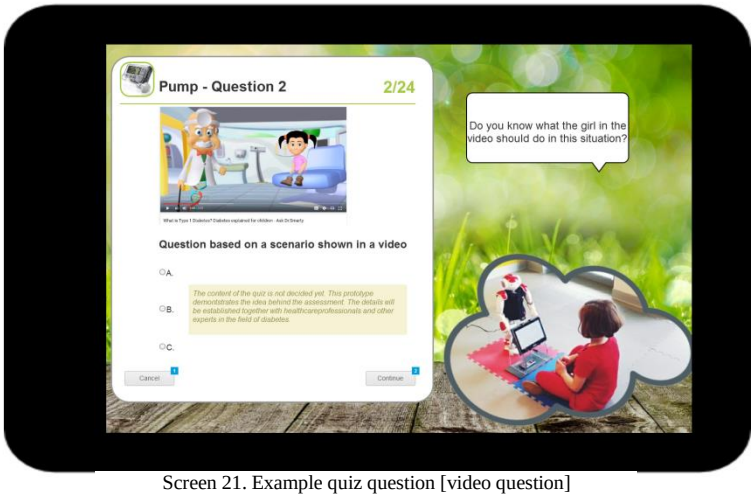

Screen 18. Robot explains the quiz and ask the child to press on start, when she is ready.



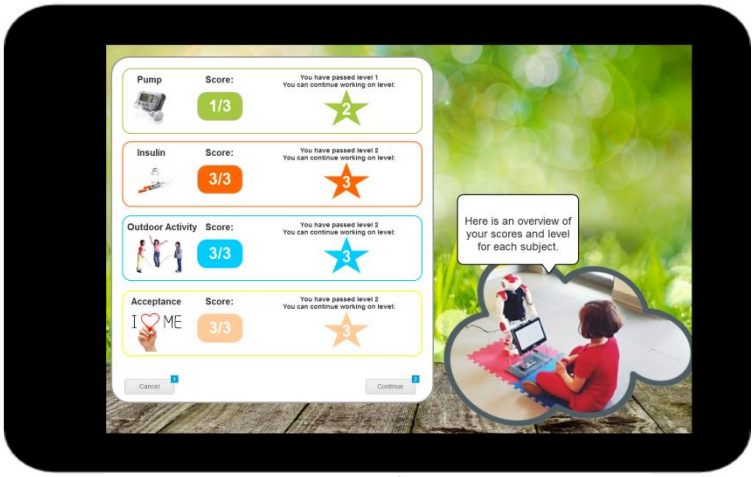

Screen 19. Robot shows all the topics of the quiz



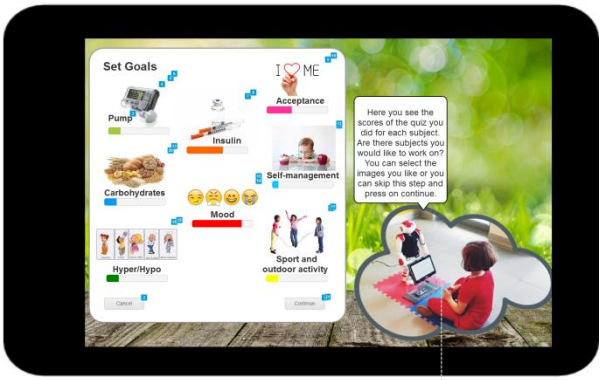

Screen 20. Example quiz question [multiplechoice]



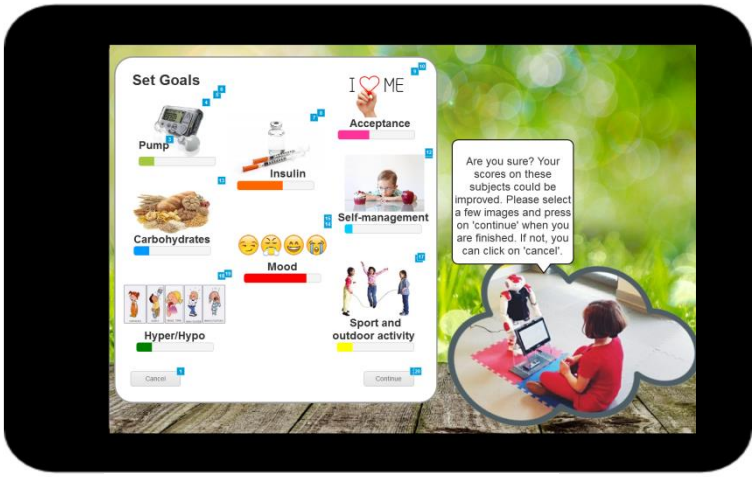

Screen 21. Example quiz question [video question]



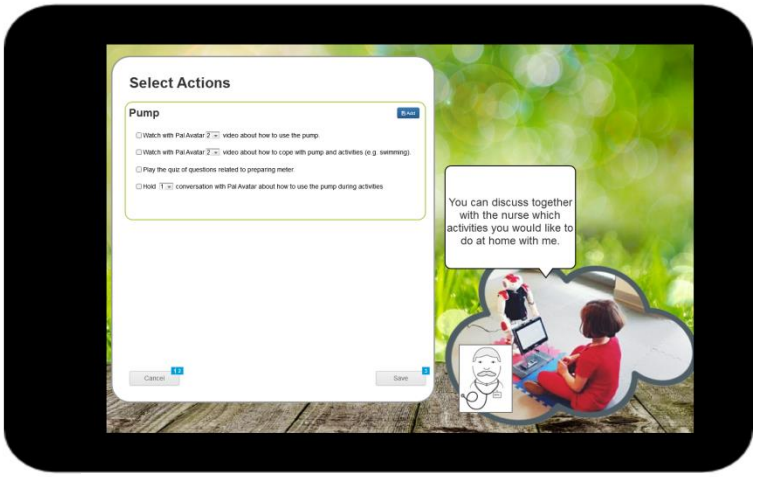

Screen 22. Results of the assessment



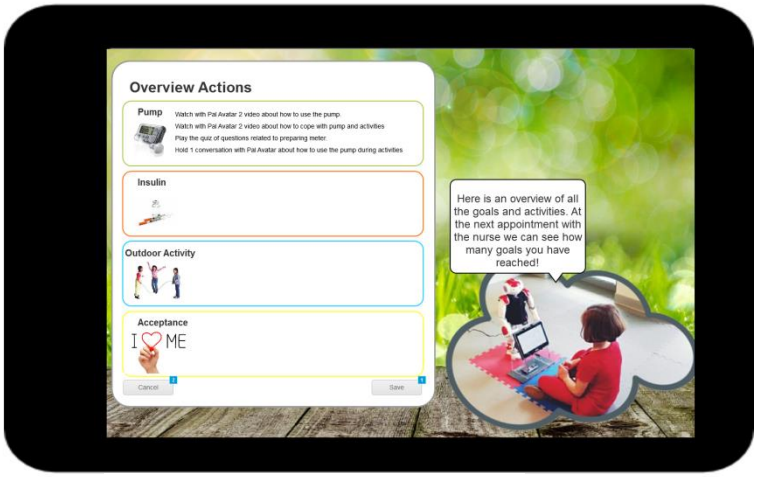

Screen 23. Robot asks child to set goals by selecting images followed by showing it to healthcare professional and discuss about it.



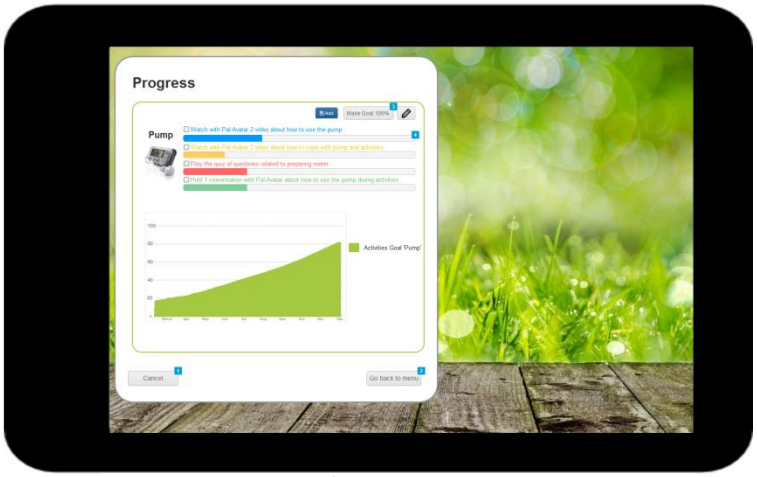

Screen 24. Robot reacts if child does not set goals




Screen 25. Robot motivates child to select actions together with the healthcare professional in order to achieve the goals.

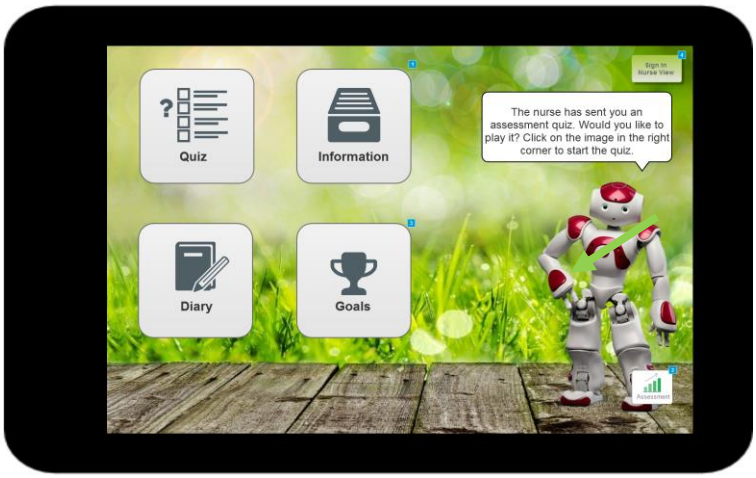



Screen 26. Overview Actions

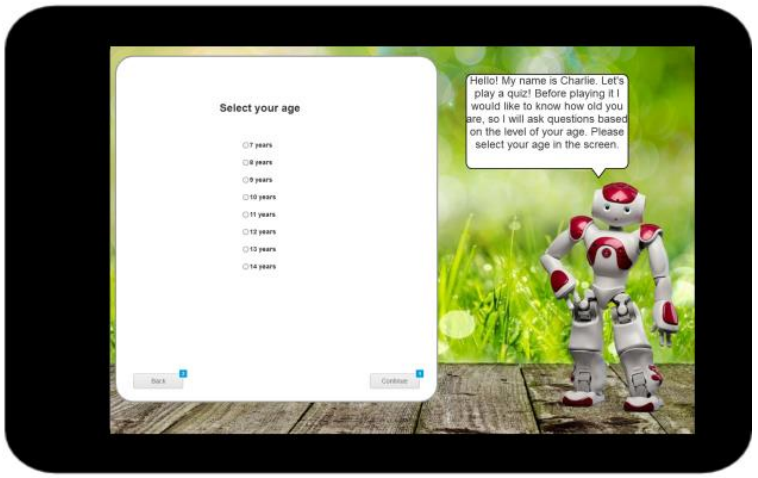



Screen 27. healthcare professional and child can look together at the progress of the actions, whereby the healthcare professional can edit the progression.

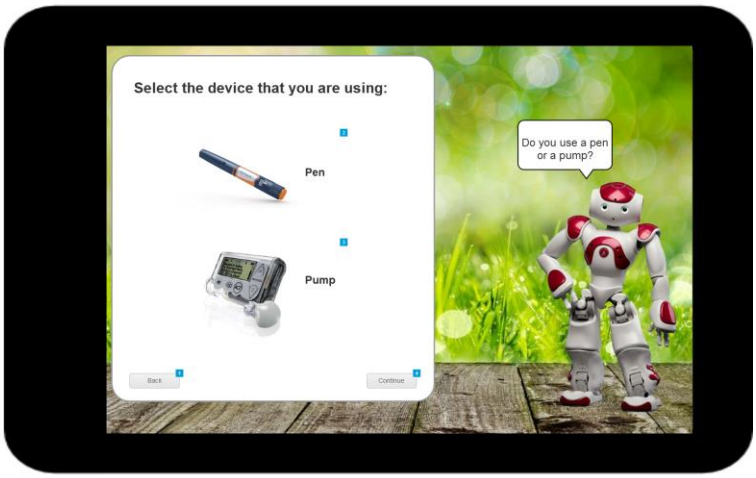
**Scenario: Assessment at Home [Child and PAL avatar]**




Screen 28. PAL avatar explains child that the healthcare professional has sent an assessment and motivates the child to play this game together.

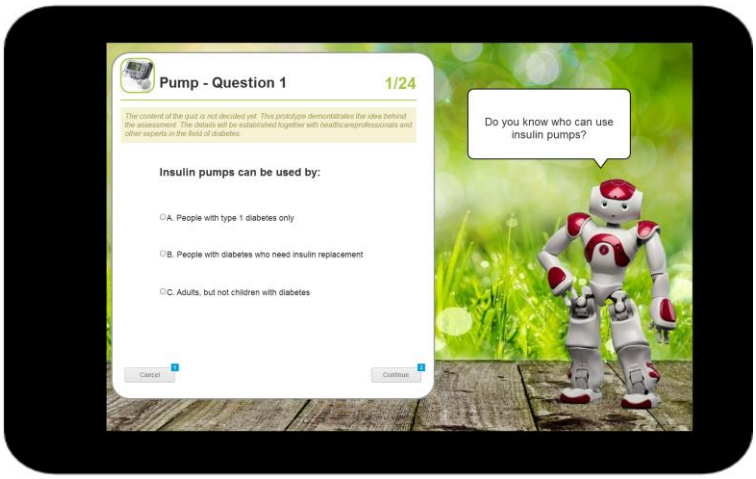



Screen 29. PAL avatar asks child to select his/her age.

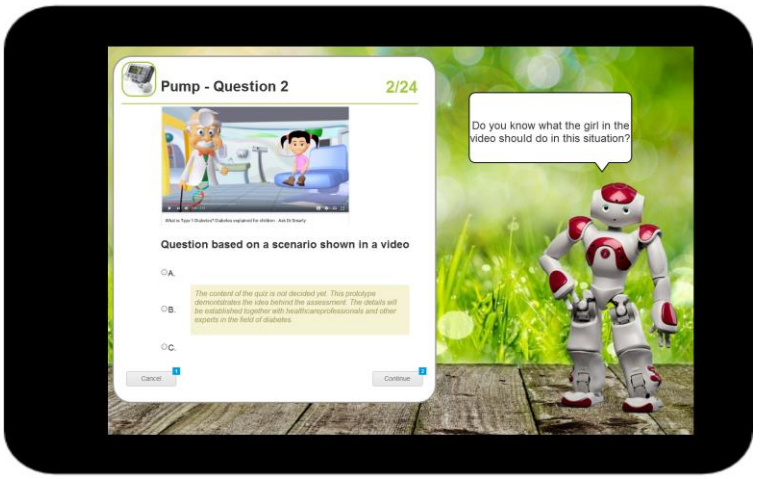



Screen 30. PAL avatar asks child to select his/her device.

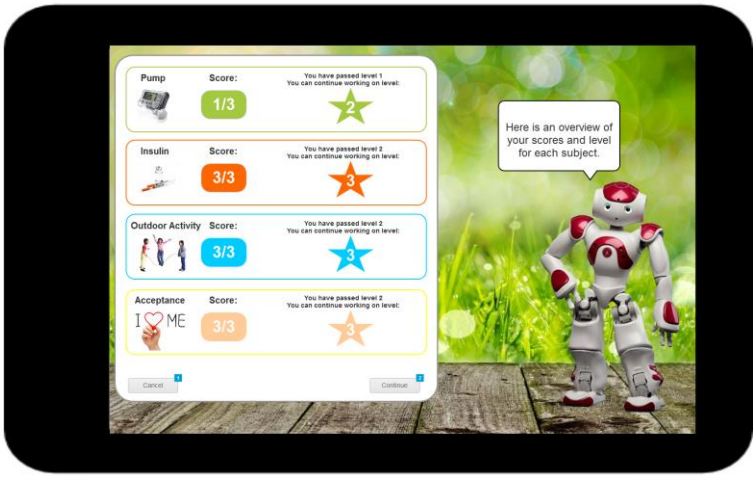

Screen 31. PAL avatar shows all the topics of the quiz



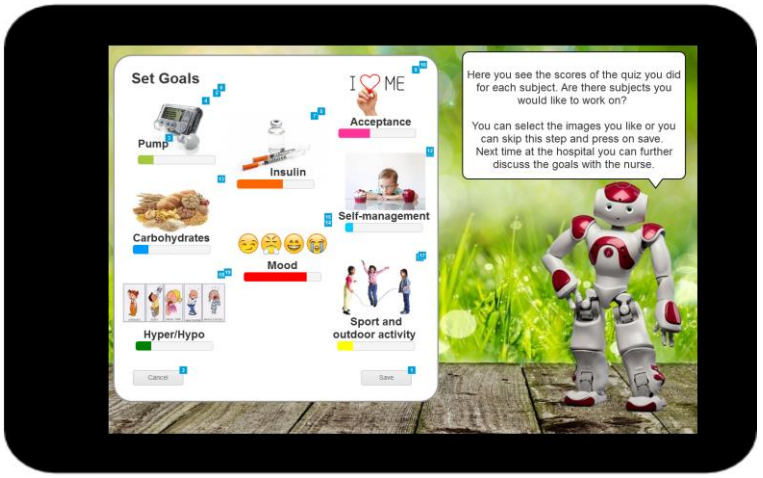

Screen 32. PAL avatar asks child a MC question




Screen 33. PAL avatar asks child a video question



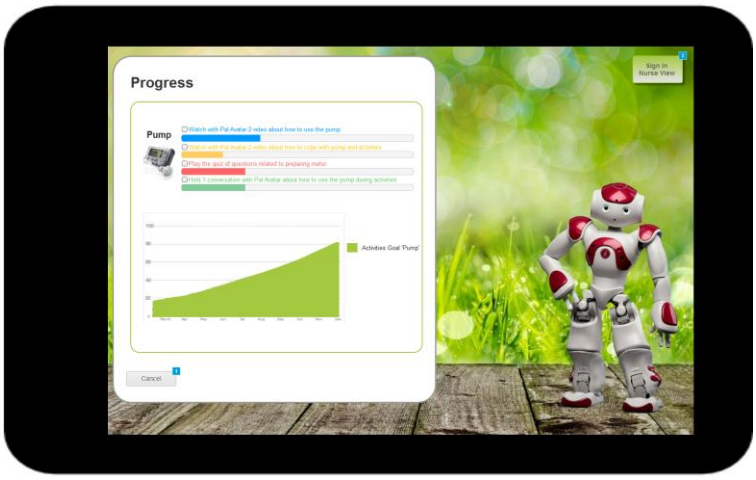

Screen 34. PAL avatar shows child his/her results of the assessment



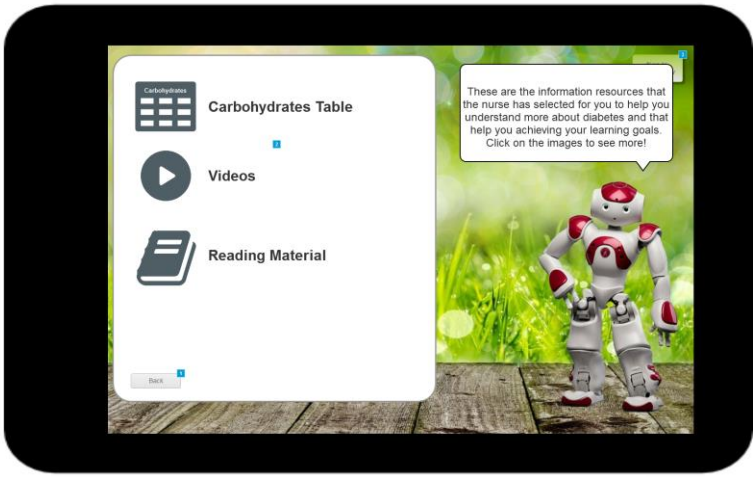

Screen 35. PAL avatar explains child that he/she can set goals by selecting the images and then click on save or he can also skip this step. Next time at the hospital the child can show these images to healthcare professional and discuss together about it.

**Scenario: PAL avatar explains child about the new functionalities in MyPAL**

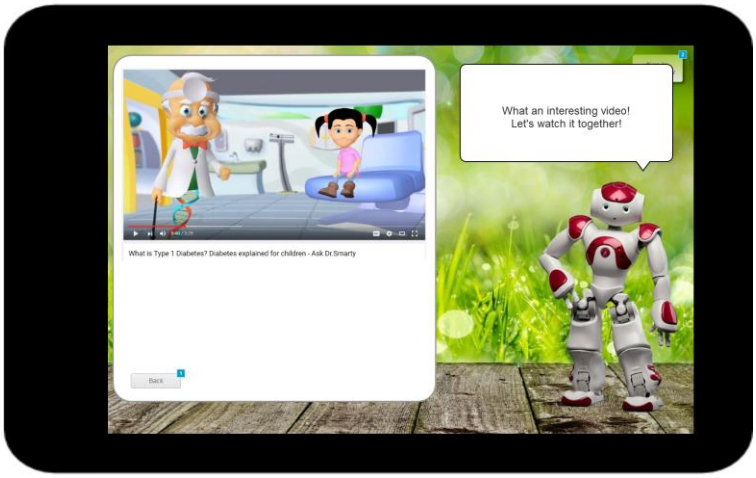

Screen 36. PAL avatar explains child about the button ‘information’ and ‘goals’.




Screen 37. PAL avatar shows that after pressing ‘goals’ button an overview of the progress in achieving goals is shown.




Screen 38. PAL avatar shows that after pressing ‘information’ button different educational material are available.




Screen 39. PAL avatar shows the child that healthcare professional has selected this youtube video to watch together.

# Appendix F: SUS Score

**Explanation User score:**

The user score is the score respondents give in the questionnaire for each question, whereby the score is based on a 5 point scale ranging from "strongly agree" to "strongly disagree".

**Explanation SUS score:**

For all the odd numbered questions: subtract one from the score.

For all the even numbered questions: subtract the response FROM 5.

Next, the total score will be add up and then multiplied by 2.5.

This gives a total possible score out of 100. The average SUS score is 68.

**SUS Score Scale**

| Scale | Score |
|---|---|
| A+ | 90+ |
| A | 80 - 90 |
| B | 75 - 80 |
| C | 60 - 75 |
| D | 50 - 60 |
| F | 40 - 50 |

Calculation of mean score (see table 2 on page 7):

(75 + 82.5 + 82.5 + 62.5 + 92.5 ) / 5 = **79**