What a Robotic Companion Could Do for a Diabetic Child

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***Abstract*— Being a child with diabetes is challenging: apart from the emotional difficulties of dealing with the disease, there are multiple physical aspects that need to be dealt with on a daily basis. Furthermore, as the children grow older, it becomes necessary to self-manage their condition without the explicit supervision of parents or carers. This process requires that the children overcome a steep learning curve. Previous work hypothesized that a robot could provide a supporting role in this process. In this paper, we characterise this potential support in greater detail through a structured collection of perspectives from all stakeholders, namely the diabetic children, their siblings and parents, and the healthcare professionals involved in their diabetes education and care. A series of brain-storming sessions were conducted with 22 families with a diabetic child (32 children and 38 adults in total) to explore areas in which they expected that a robot could provide support and/or assistance. These perspectives were then reviewed, validated and extended by healthcare professionals to provide a medical grounding. The results of these analyses suggested a number of specific functions that a companion robot could fulfil to support diabetic children in their daily lives.**

I. Introduction

Type 1 Diabetes Mellitus is an auto-immune disease characterized by a failure of the body in the production of insulin. It is a widespread disease; just in US it affects 8.3% of the population [1], and the World Health Organization has forecast that the number of diabetic patients will grow from 171 Million in 2000 to 366 Million in 2030 [2]. People living with this disease must carefully manage their insulin intake (either by insulin pump or manual injections), balancing it depending on energy intake (typically eating and drinking) and expenditure (physical activity, sleep, etc.) throughout the day and night. Furthermore, diabetic patients must test their blood glucose level, by pricking their fingers five or more times a day. Incorrect management of blood sugar levels (both too high and too low) can generate life-threatening situations, causing serious damage to bodily tissues in the long term (e.g., eyes, kidneys, etc.).

Being a child with Diabetes is particularly challenging, because it forces individuals to face the cognitive and emotional difficulties of accepting and living with the disease. For this reason providing proper support to them is of paramount importance. In this study we targeted children aged between 7 and 12 years old, as this is the age range in which, depending on the individual level of maturity, children start to self-manage their disease and make their first independent choices (e.g., about food, sports, etc.).

It has previously been theorized how a Robotic Companion could support diabetic children [3]: the scope of this work is to further investigate this possibility with a close interaction with all stakeholders, namely diabetic children and their formal and informal caregivers. The methodolgy for the investigation consists of three main steps: 1) elicitation and understanding of the expectations that diabetic children have of a potential robotic companion; 2) validation of the results of the outcomes of step 1 with healthcare professionals (doctors, nurses, psychologists, etc.); and 3) elaboration of a list of the robot's role and functions.

II. Background

Understanding from children how they live with diabetes is not an easy task. Several attempts have been made in the past, making use of a number of different methodologies.

The Diabetes Attitudes Wishes and Needs (DAWN) is a very important global programme to improve psychosocial support for people with diabetes focusing on the person behind the disease. DAWN was initiated to increase the understanding of how people perceived their diabetes in order to develop better outcomes for treatment. In view of the results of the study and the observation that diabetes in children has specific clinical and psychosocial characteristics, the DAWN Youth [4][5] programme was designed. Analyzing this program, Kadohiro et al. [6] reports that 35% of the 6,789 respondents reported to having poor psychological well-being; 47% missed school or school activities because of their diabetes; 39% experienced a major to moderate effect on their school performance; and 12-17% of them found that diabetes regularly causes them embarrassment, resulting in discrimination, and limits in their social relationships. In general, support received at school was reported to be worse than from any other source (family, healthcare services, etc.).

Freeborn et al. [7][8] used focus groups with 16 children to try to identify challenges and to understand experiences in the school setting of children and youth with type 1 diabetes from their own perspectives. They found that the three main challenges for children with type 1 diabetes are: low blood glucose, self-care activities and feeling different and/or alone.

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Miller [9] explored the main issues that children with diabetes have through the use of interviews directly with children and their parents, and opinions elicited through examples of daily life situations. Henkemans et al. [10] used semistructured interviews with children, parents and diabetes caregivers, although the pool of participants was relatively small and homogeneous, which provided a picture of the specific Dutch approach to diabetes management. These methods suffer from the apparent desire of interviewees to appear more healthy than they actually are, and to be approved by the interviewer [11]. Therefore, there is a need to explore these issues using methodologies that overcome the problems with interviews.

III. Goal of the study

The goal of this study was to understand how a robotic companion could provide proper support to diabetic children, in different situations of their daily life when they would most need it. In order to minimise the aforementioned drawbacks of structured interviews, a different evaluation methodology was used. This consisted of setting up a creative and playful environment where children were free to express their ideas without being judged nor constrained, and where they were able to simultaneously explore the robot's capabilities.

IV. Methodology

Families (N=22) with children suffering from diabetes where invited through the patients' association Sostegno70 to an educational day at the Science and Technology Museum of Milan, in October 2012. Overall, the initiative saw the participation of 32 children (ages from 5 to 13 years old), 22 of whom had diabetes (ages from 9 to 13 years old), and 38 adults. The 10 healthy children included were siblings of the diabetic children invited for the event, and therefore had an understanding of the implications of the disease, and, in the case of older sublings, also some experience of aiding in the disease management.

This population was divided into three groups, and participated separately on three consecutive Saturdays in October 2012. Each group was further divided into two subgroups, following parallel activities (see figure IV for an overview of the space used): one was an educational activity learning to count carbohydrates in foods, and the second was a brainstorming discussion about the robotic companion (Nao, Aldebaran Robotics). On average, we were able to work with six small groups of 5-6 children, and 6-7 adults. The schedule for each Saturday session was:

1) Initial introduction: consisting of general information about the initiative, introduction to the schedule of the day, presentation of the Nao robot (which introduced itself with a pre-prepared script), and presentation of an interactive game the children could play with the robot (the "Sandtray").
2) Division into small groups: the children and adults were separated for their separate activities.

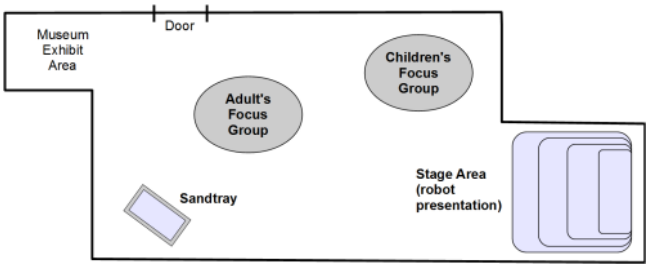

Fig. 1. Schematic of the room used for the brainstorming sessions at the Science Museum of Milan: the relative locations of the three activities are shown (not to scale).

- Adults: Parents and relatives of the children were presented more details about the experiment, and they were led through and asked to sign an informed consent form. They were then provided with an optional questionnaire. The questionnaire consisted of six closed questions concerning what they thought about the robot and its potential usefulness; and three open questions to collect their opinions on what they thought the robot could do at home, school, and in the hospital for their children. All participants filled in the questionnaire, even though it wasn't mandatory.
- Children: The groups of children were presented with a poster of the Nao robot and post-its of different colors (figure IV). Each color represented a different domain (home, school, hospital), and they were invited to write what Nao could do to help them in different situations in these environments. Every idea was written individually by each child, who was then invited to go to the poster and attach the post-it to it wherever s/he desired. The activity was lead by psychologists, who supported the children in the elicitation of the ideas, and managed the younger children not able to write (a couple of children were indeed in the pre-primary school age). At the end of this activity, the experimenter read some of the ideas generated and discussed it with all of the children in the group.

3) Conclusion: a final demonstration of the robot's abilities to the small group (both adults and children), with a number of interactive demos, and final thanks.

During the brainstorming sessions, children had the chance to interact directly with the robot, in a one-to-one game. By playing this game with the robot, each of the children were able to relate their opinions of the robot expressed in the brainstorming discussion to a personal experience (the behaviour of the robot was independent of the purpose of the brainstorming session). The game itself was a food-sorting task (sorting low carbohydrate-content foods from high carbohydrate content foods), played on a large touch-screen in collaboration with the robot [12] (figure IV). The robot was controlled remotely by a human operator, who was

Fig. 2. The robot poster used by the children to gather their post-it notes.

hidden so that the children thought that the robot was acting autonomously. Indeed, a *post-hoc* analysis of the observed interactions indicated that the children viewed the robot as a social actor in this game context [13], which may have facilitated their view of the robot as a potential robotic companion.

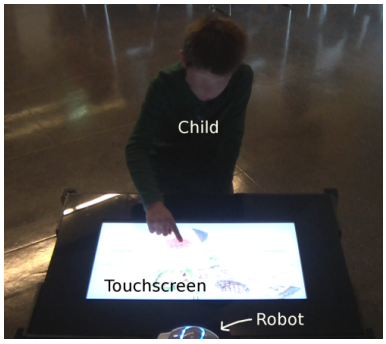

Fig. 3. Overview of the Sandtray interactions in the Science Museum: by interacting with the robot in parallel with the brainstorming sessions, the children had an opportunity to ground their opinions of the robot in an interaction experience.

V. Results

Table I reports a summary of the suggestions of the possible use of the robot in the three main contexts (home, school and hospital) received during the brainstorming interactions.

As reported in this table, most of the suggestions were related to the home environment. From the discussions, this trend was informed by two general considerations: 1) that children would love to have the robot as a companion in their daily life for entertaining activities (e.g., playing games, sports, role-playing, playing videogames, etc.), and 2) that

TABLE I

Suggestions received, divided per domain

	School	Home	Hospital	Total
Adults	43	51	42	136
Children	49	68	47	164
Total	92	119	89	300

adults would like the children to have a constant reminder (through the robotic companion) of the daily commitments for diabetes management.

The data collected were organized using Affinity Diagrams [14], by means of grouping similar suggestion into clusters which were expressing the same concept (even if with different wordings). Clusters were then analyzed and merged, after which seven main themes were identified, which will be described and exploded in this section. Examples of the children's and adult's written ideas are presented for each theme, translated from the original Italian as they were written. We tried to translate everything as faithfully as possible, for example with childish sentences, with the same grammar errors as in the original language, with the same slang (e.g. they use the terms "hypo" and "hyper" for episodes of hypoglycemia and hyperglycemia, respectively, as they are quite familiar with them), etc.

A. Entertainment

The majority of the suggestions were related to entertainment (105 of the suggestions can be considered related to it), and this may be predicted, as the appearance of the robot Nao has cartoon-like qualities, is small, and has a non-threatening appearance by design. Its effect on both children and adults is always impressive and it is not surprising that both children and adults imagine a possible role for the robot as an entertainer. Suggestions are very rich in this sense, and sometimes unrealistic.

1) Examples: "Play music with me", "Help me to play volleyball", "Play chess with me", "Play with me and my friends", "play football", "swim with me", "watch TV together", etc.

It is interesting to note that many children want to play videogames with the robot, which implies that they don't consider it an "evolved" videogame, but rather a peer they can play with. Some of the suggestions under this topic were provided in the "hospital" context, meaning that both children and parents feel the need for a more friendly hospital environment.

2) Examples: "Nao could help to see the hospital as a playful environment, rather than a boring one.", "Make the hospitalization more pleasant", etc.

In many cases, this role of entertainer is seen also as an important possibility for the child to distract from his/her problems (e.g., injections)

3) Examples: "Distraction and gaming", "Nao could be used to distract", etc.

B. Self-management

One of the main issues of children suffering from Diabetes is the complex set of daily tasks that they have to manage. Miller calls these tasks "Daily Discipline" [9], and as most of these are in fact under the control of the children directly (sometimes with the supervision or support of an adult), we call this recurrent topic "self-management". Within this category we can distinguish between three main subclasses:

- Actual self-management: Both children and parents expressed clearly the actual need of the children when they have to perform diabetes-related tasks.
  1) Examples: "Nao could help in measuring glycemia during night", "It could help in counting carbohydrates", "Remind me to inject insulin", "Help me to decide the insulin doses", "Record correctly my measurement", etc.
- Self-management monitoring: Besides seeing a possible role of the robot to provide a direct help to the children, some parents also expressed the desire to have feedback on how their children are performing with their self-management, and they think that the robot could report this to them directly.
  2) Examples: "Check that my son doesn't eat outside of regular meals", "ensure that my son checks his glycemia", etc.
- Self-management support: Finally some considerations were related to the parent's hope that the robot would act as a support for other adults (especially school personnel) who also need to assist their children.
  3) Examples: "Help teachers and janitors in the diabetes daily management, especially in cases of hypo- and hyperglycemia", "Help the teachers besides my son, as they have twenty more children to manage, all of them with different needs", etc.

C. Knowledge increase

Many suggestions (at least 57) can be classified in this theme. The suggestions came both from children (38 suggestions) and parents (19 suggestions), even if in many cases with different perspectives. Furthermore, we can distinguish between knowledge in general (e.g., doing homework, or learning to do something) and diabetes knowledge in particular (e.g., learning procedures, insulin management, etc.). A lot of children believe that the robot could be a great support to help in homework, especially with mathematics.

1) Examples: "Help to learn to write", "Help to solve math problems", "Learn the multiplication tables for 8 and 9", "Help with homework when one really can't do them", etc.

Many adults expressed instead the possible usefulness of the robot in teaching their children about diabetes, by means of making this learning process more fun and engaging.

2) Examples: "Explain diabetes in a way that is clear/simple/intuitive", "Learn carbohydrate counting and insulin pump usage", etc.

Finally some interesting suggestions were related to the use of Nao not for the education of the diabetic child directly, but of the other children (e.g., schoolmates) and adults (e.g., teachers, peers' parents, etc.).

3) Examples: "Give a lesson to the classmates about diabetes", "Nao should be introduced in the schools especially to improve parents' knowledge, as many times they consider diabetes as an infectious disease, and they suggest that their children stay away from diabetic children.", "Most of all to improve teachers' knowledge about the disease", etc.

D. Self-confidence and motivation

Self-confidence and motivation were two recurrent themes, mentioned both by adults and children. Especially adults believe that the robot could help to convince children to do things they usually find difficult or boring, by means of making these activities more fun or by somehow rewarding the children.

1) Examples: "Congratulate the children when they do something correct, motivation", "Congratulate the children for their results", "Motivate him in doing his homework", "Nao could be an incentive to be more motivated in several activities", "Help her to reason about things she doesn't want to do, pushing her to do them", etc.

Furthermore in many cases it seems that the children feel a sense of inferiority with respect to their peers, and many parents believe that Nao could help either psychologically or practically.

2) Examples: "Improve his self-esteem and make him feel important.", "It could speed-up the moment of insulin injection for lunch and morning snack, so that she's ready, together with the other, children to eat", "Help him to feel less different", etc.

E. Sensitive Listening

By reading the comments from both parents and children, it seems that there is a shared feeling of burden, which on many occasions the children are not properly able to express. Interestingly, both parents and children believe that the robotic companion could do a lot by simply listening to the children's problems. The most explicative comment received from a parent is as follows.

1) Examples: "Listen to the possible discomforts of the child that she doesn't express even to her family or friends. Those most intimate and desperate thoughts, that she's not able to translate into adults' language." This was one of many comments shared by other parents as well.

2) Examples: "Nao could comfort children in sad moments", "To unload when they are angry or frustrated", "Nao can comfort him, especially when he's bored in hospital", etc.

Children expressed similar feelings, though with different language expressions.

3) Examples: "Nao could be my psychologist when I'm sad", "Cheer me up when I'm sad", "I'd share all my secrets with Nao", etc.

F. Attention catcher

Another interesting set of suggestion was related to the intrinsic ability of the robot to attract and maintain the

children's attention. This is considered an important asset to be able to also involve the child in tasks that are usually considered boring but important. One example is paying attention to the diabetes lessons that are provided in the hospital, but many times this is used also as a suggestion for normal lessons that children follow at school.

1) Examples: "Nao could be a stimulus in the teaching activity, especially to improve the ability and quality of the attention", "Nao could teach us how many carbohydrates a meal contains", "Nao could help my teacher to teach", etc.

VI. Results validation and proposal of solutions

The set of suggestions, recommendations and requirements expressed by the diabetic families involved in the experiments and brainstorming sessions were carefully investigated by the authors, and they were discussed with healthcare professionals of San Raffaele Hospital, who are in daily contact with diabetic children in the Pediatric Department. We interviewed two psychologists, one nurse, one nutritionist and one diabetologist. This section seeks to provide for each theme a revision with the opinion of the healthcare professionals and possible suggestions of concrete activities to do with the robotic companion in each area.

A. Entertainment

The fact that the robot should be first of all an entertainment for the child is a shared opinion among all the experts interviewed. San Raffaele Hospital, as well as many other hospitals, already includes in their physical and logistical planning dedicated areas and activities for the children to play, to be distracted and to have fun. The robotic companion should be designed following the same principle. Creating a character which is fun and entertaining can not only be an effective strategy to distract the child from her condition and to make the hospital environment more friendly, but it is also useful to create a bond with the child, on top of which other strategies could be built (e.g., education).

1) Solution: In this theme, any game which entertains and distracts the child is effective. In the various experiments performed at San Raffaele Hospital, it was noticed that the humanoid robot Nao is particularly attractive for children, especially when it uses its body during the interaction (e.g., movement imitation games, dance games, etc.), rather than when it is just speaking (e.g. a quiz game).

B. Self-management

The theme of self-management is of central importance not only for children and parents, but also for the healthcare professionals. Indeed the interviewed experts underlined the importance of the use of the robot particularly in the target age of this study, for the reasons explained in the introduction.

1) Solution: The experts and the authors proposed an activity where the robot could help the child to setup and maintain a diary to log the pathology development, as well as the insulin doses. The child's role would be to fill in this diary, and discuss it ona regular basis with the robot. The robot should ask the child data about her diary, ask about particular events (hypo, hyper, etc.), help the child to reason about why certain situations happened, congratulate the child on positively managed situations, encourage her in case of badly managed situations, and derive the lessons learned.

C. Knowledge increase and Attention catcher

Knowledge about the disease and its symptoms is the first important asset that children and their families are provided with when they arrive at the hospital. In San Raffaele, as at other hospitals, specific training classes are held for children and parents to understand and manage the disease. The interviewed healthcare professionals believe that the robot could be an important support in the learning process. We can distinguish two phases in the learning process: knowledge acquisition and knowledge retention.

1) Knowledge acquisition solution: As far as knowledge acquisition is concerned (and the role of attention catcher of the robot) the interviewed experts proposed to use the robot as a lessons mate, which could actively participate either as a teacher deputy in explaining the lesson or as an interested learner who makes important questions during the teacher's explanations.

2) Knowledge retention solution: For knowledge retention, the suggested activity with the robot is to play games with the concepts learned in the lessons with teachers, nurses and doctors. The classic example is a quiz game, which was widely experimented with in San Raffaele Hospital, but other learning games could be proposed.

D. Self-confidence and motivation

Building self-confidence and motivation is very important to make the child autonomous in managing the disease in every condition of her daily life. Especially the psychologists of the pediatric department were very interested in further developing this theme with the robot proposed the following solution.

1) Solution: The proposed activity with the robot is similar to an activity that psychologists used to do with puppets. The activity consists of a "role playing game" where the child plays the role of the doctor and the robot plays the role of the patient. The robot will start to present a situation in which it pretends to have some diabetes-related feelings or symptoms, and will ask the child for advice. The child can suggest to the robot how to proceed and it will see the consequences of any action in the robot. In this way the child can experiment with different situations and be prepared to face them, in case they ever happen to her. It is not just a matter of "training", but really to acquire the self-confidence needed to manage difficult situations instead of relying solely on the intervention and help from adults.

E. Sensitive Listening

The possibility to let the children open and share feelings and emotion is particularly important. The psychologists of San Raffaele Hospital tried to achieve this goal in special events related to diabetes: children were invited to freely

discuss some of their main difficulties in managing diabetes, alone in a room and speaking to the camera. The activity gave very interesting results, with the children disclosing more than expected and tackling also with difficult personal issues. Experts agreed with the children and parents that the robot could be helpful in this respect, especially if it manages to become familiar enough with the child to be seen as a peer.

1) Solution: There is not a specific activity that can be designed to achieve this goal, but what could be done is to add to the robot "sensitive listener" behaviors during other kinds of interaction. For example, in current experiments at San Raffaele Hospital, the robot is playing a quiz game with the child, but sometimes it interrupts the game to provide a personal question to the child (e.g., about how long she's living with Diabetes, or what does she do when a specific symptom comes out, etc.), encouraging her to share her feelings and being very grateful when she does so.

VII. Conclusions

This study has provided a number of important perspectives from all stakeholders involved in child diabetes care. Primarily it was a creative and entertaining way for children to get closer to the robot, thinking about how and where they would like to find it in their daily life by imagining possible scenarios of interaction.

Through the highly engaging technique of brainstorming, the children were activated through the mediation of a facilitator to think how the robot could be useful in their different daily life settings, so they could feel as active parts in a project being created for them. Also the adults were engaged, by asking for their help to lay the foundations for a long-term work, with the underlying objective of improving their sense of self-efficacy and to empower them: "today you are the expert and we need your help", whereas diabetes may elicit a sense of powerless and frequently puts families in the position of passivity for medical procedures and exams.

What seems to emerge in particular is a child's perception of the robot as someone at their own level (a peer and companion), but at the same time as someone who can act as a mediator between the child and situations perceived as difficult to deal with, in a sort of "playful support". Indeed children imagine that the robot could distract or comfort them during insulin injections, or could hug them and make them smile when they are sad. It should however be noted that the role of individual differences in these generalisations requires further assessment.

The observations of the parents reflect more the concerns related to their daily children management, with particular attention to diabetes therapy, and they believe that the robot could help their need of control (of correct glucose monitoring, counting carbohydrates, record glycemia measurements, etc.). We have to consider that in families with a diabetic child, the disease becomes a part of the relationship between parents and their child, with its painful routines, often difficult to accept and manage. The robot, in their perception, through its entertaining and friendly appearance, seems to become a distraction from medical procedures or a means to deal with difficult moments more peacefully, especially during hospitalization.

We summarize by observing that parents focused mostly on a robotic companion that could help, in different ways, their children to manage diabetes, whereas children perceived Nao as a someone who could be with them; not only to help or support about diabetes, but mainly to share the daily life experiences and difficulties, common to most of (healthy) children.

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