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

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Abstract—**Children with diabetes can benefit from keeping a diary, but seldom keep one. Within the European ALIZ-E project a robot companion is being developed that, among other things, will be able to support and motivate diabetic children to keep a diary. This paper discusses the study of a robot supporting the use of an online diary. Diabetic children kept an online diary for two weeks, both with and without remote support from the robot via webcam. The effect of self-disclosure, empathy and remote physical presence of the robot was studied on children's use of the diary and their relationship with the robot. Results show that children shared significantly more personal experiences in their diaries when they were interacting with the robot. Furthermore, they greatly enjoyed working with the robot and came to see it as a helpful and supportive friend.**

Keywords—social robot; remote robot; diabetes; diary; embodiment; adherence; compliance; bonding; engagement; relationship; child-robot interaction; human-robot interaction

I. INTRODUCTION

It is estimated that worldwide more than 490 thousand children between the ages of 0-14 suffer from diabetes mellitus type 1, and this number continues to rise explosively [1]. Diabetes is a chronic illness that impacts a child's life in almost every aspect. Effective self-management of diabetes is complex and involves many varied activities related to dosing insulin, monitoring metabolic control and regulating diet and exercise to name just a few. This can be especially challenging for children that are diagnosed at a very young age. They frequently have trouble coping with their diabetes [2], and are at risk for developing depression, anxiety disorders or eating disorders [3][4][5]. Health care providers advise children to keep a diary to monitor their health and how they feel on a daily basis so that appropriate treatment adjustments can be made [6]. A diary provides insight into patterns between blood glucose values and daily activities so that the child can better manage his/her diabetes. But despite this advantage of keeping a diary, children rarely take the time to do it or they do not see the value of keeping a diary.

The EU-funded ALIZ-E project www.aliz-e.org aims to develop a social robot to support chronically ill children in their self-management. The scenario in which the robot is being tested is based on a medical setting where children recently diagnosed with diabetes spend one or two weeks in the hospital. During this time, the child and its parents are intensively trained and educated to manage the child's diabetes. But of course self-management of diabetes does not end there. It is an active and lifelong process that involves shifting and sharing responsibility for care tasks and decision-making between parents and child. The ALIZ-E project focuses on the potential role of a robot (Figure 1) in this process as an educator, motivator and companion that remains interesting to the child on the long term [7].

Fig. 1. NAO robot by Aldebaran Robotics

This paper describes an experiment which aims to improve children's diary adherence by means of a social robot. We created a scenario in which diabetic children keep a diary from home for two weeks, intermittently interacting with the robot via video-conferencing software. We studied the effect of the robot on the children's diary adherence, their engagement in the activity and their relationship with the robot.

II. SOCIAL ROBOTICS

Social robots are increasingly designed to be our pets, assistants, teachers and even emotional companions [8]. They can positively affect people's motivation and compliance in areas such as education, health and well-being [9]. The effectiveness of a social robot as a motivator largely depends on its ability to persuade its user. Persuasion is defined as "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object or action" [10]. In this study, the issue we are addressing is the low diary adherence of children with diabetes. The robot attempts to persuade the child to keep a diary by using a variety of means that have been proven to be effective in human-robot interactions. Directly coercing the child into better keeping a diary is not an option for two reasons: first, coercion often has the opposite effect and causes the child to rebel even more [11]; and second, from a

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practical standpoint it is impossible to uphold this approach because the parents will not always be around to check up on their child. Rather than making active attempts to change the child's attitude and behavior, the focus should be on positively reinforcing the child's actions and utilizing the potential bond between the robot and the child as an incentive for the child to keep a diary.

To cultivate long-term relationships with users, the robot needs to engage in social dialogue. Social dialogue includes things like greetings, chatting about general topics like the weather, and exchanging personal preferences [12]. Self-disclosure and empathy are known to greatly contribute to the closeness between conversational participants [13], [14], [15]. This effect is stronger with a physically embodied robot than with a virtual agent. There are many other factors we could consider which have the potential to positively influence children's diary adherence and long-term relationship with the robot. However, we feel that investigating the effects of self-disclosure, empathy and embodiment provide a good starting point for this explorative research. These aspects can easily be implemented into the robot's dialogue and behavior.

A. Self-disclosure

Studies have shown that self-disclosure plays a central role in the development and maintenance of relationships as well as psychological well-being [13], [16], [17], [18]. Self-disclosure is defined as "sharing information with others that they would not normally know or discover" [19]. Once a person engages in self-disclosure, it is implicitly expected that the other conversational partner will also disclose information (norm of reciprocity). Self-disclosure has been linked to a person's likeability [16]. People who engage in intimate disclosures tend to be liked and trusted more than people who disclose at lower levels. People tend to also like robots better when they disclose affective rather than task-related information in collaborative tasks [20]. Mutual affective self-disclosure between the child and the robot can contribute to the depth and quality of their interaction, and ultimately their relationship. Self-disclosure also contributes to the diabetes self-management of the child. Sharing daily experiences in the diary and reflecting on this information can help the child gain insight into how they can better manage or cope with their diabetes. In order to encourage the child to disclose information, we propose to utilize the reciprocal nature of self-disclosure and have the robot frequently disclose information about itself to encourage the child to do the same.

B. Empathy

Empathy plays a key role in patient-centered therapy, because it implies the apprehension of another's inner world and a joint understanding of emotions [21]. One of the most comprehensive definitions of empathy is by Davis [22], who defined it as "the capacity to take the role of the other, to adopt alternative perspectives vis-à-vis oneself and to understand the other's emotional reactions in consort with the context to the point of executing bodily movements resembling the other's". Robots cannot feel empathy, but they can emulate it in their behavior, for example by [22]:

- Showing empathic concern for others;
- Taking the perspective of another;
- Emotionally identifying with fantasy characters in books, films, etc.;
- Expressing negative feelings in response to the distress of others.

We propose to incorporate empathy in the robot's behavior by showing sympathy or concern when the child says to be feeling down, and by reacting positively when the child is in good spirits. The robot could also express its concern in asking the child how he or she handles certain issues related to diabetes (i.e. fear of exercising or pricking insulin in public).

C. Embodiment

Social robots do not necessarily need a physical body to interact with their users. Their tasks can often be performed just as well by a virtual 3D representation or avatar of the same robot, which costs considerably less and is much more robust. But having a physical form does offer substantial benefits compared to virtual robots. Embodied robots (robots with a physical presence) were found to be more appealing and perceptive of the world around them than non-embodied robots [23]. Participants' impression of the robot's watchfulness, helpfulness, and enjoyableness was significantly affected by embodiment. In a study on a socially assistive robot exercise coach for the elderly [24], participants strongly preferred a physically embodied assistive robot over the virtually simulated one. The interaction with the physical robot was rated as more enjoyable and useful. Physical embodiment has also been found to evoke a higher degree of user engagement and presence [25].

The positive effects of having a physical body were shown to still be prevalent when the robot is shown remotely via a camera. The social presence of a remote physical robot was almost the same as a robot that was located physically near the user [26]. A remote projected robot and a physically present robot were found to be equally engaging and elicited equal disclosure from the user. We propose to show the robot remotely via a webcam so that the children can keep a diary with the robot from home, without having to travel to a laboratory or hospital to meet with the robot. However, we choose to also have the children meet with the physical robot in person before the experiment so that they know the robot is real and not just a virtual avatar.

D. Hypotheses

The effects of self-disclosure, empathy and embodiment lead us to the following hypotheses:

1) Adherence: self-disclosure of the robot encourages the child to share more information in their diaries.

2) Engagement: the remote physical presence of the robot has a positive effect on the child's engagement in the activity.

3) Bonding: the robot's empathetic behavior conveys a sense of trust and understanding of the child.

In order to test these hypotheses an experiment in a real-world setting was conducted.

III. IMPLEMENTATION

A. Robot

The NAO robot (developed by Aldebaran Robotics) was used in this experiment. NAO is well-suited for interaction with children largely due to its friendly childlike appearance. Although its face lacks the capability to display emotions, the robot is able to show a wide array of emotions through its body language. The robot in the experiment was given the unisex name "Charlie" in order to appeal to both boys and girls. A background story was written for the robot to answer basic questions about its likes and preferences, and about its reason for participating in the experiment. In the story Charlie is a hospital care robot in training and it hopes the child can help it learn more about diabetes by keeping a diary together. When the robot engages in self-disclosure, it does so keeping this background story in mind.

B. Dialogue model

A dialogue model was developed that structured the robot dialogue in an orderly fashion. The model consisted of two parts: the diary-related dialogue, and the interpersonal dialogue.

1) *Diary-related dialogue:* any dialogue related to the task of keeping a diary. This includes the login process, explaining of diary sections and filling in the diary itself. This part of the dialogue was very structured, and did not allow for much flexibility other than the child choosing what section he/she wanted to start with. Essentially this part of the dialogue was the same for every child.

2) *Interpersonal dialogue (or 'small talk'):* any dialogue not directly related to the task. There were two different types of small talk.

   o *Self-disclosure small talk* was used for the robot to share information about itself and optionally ask the child to do the same. For example, the robot told the child about its favorite pets, and then proceeded to ask the child if he/she had any pets.

   o *Diabetes-related small* talk was used for the robot to talk about what it learned in school about diabetes (e.g. doing sports when having diabetes) and ask the child some basic questions about this topic (e.g. "How do you handle your diabetes when you do sports?"), and if he/she had any fears related to his/her diabetes (e.g. fear to prick blood glucose, or fear to exercise).

The interpersonal dialogue was much more flexible in use than the diary-related dialogue. The experiment leader used these phrases at her own insight by sending the command to the robot through mouse clicks in the Wizard of Oz interface (see below). This human intervention was necessary because

the robot was not able to do this on its own. When a related topic was mentioned or when there was a moment of silence, the experiment leader could choose to use one or more of the small talk phrases. The small talk was used to enrich the dialogue between the robot and the child, with the goal of creating a bond between them.

C. Wizard of Oz

The main deliverable of the ALIZ-E project is an integrated and autonomous system comprising different modules. But because this system is developed incrementally and not all features have fully matured, some of the robot's functionality is simulated. The participants interacted with the robot which they believed to be autonomous, but which was actually controlled by the experiment leader in a Wizard of Oz (WoOz) setup. The NAO robot was capable of performing some actions autonomously, such as movements while speaking, 'blinking' of the eyes by switching LEDs on and off, and speaking (text-to-speech). Other actions could not be performed autonomously and needed human intervention. The experiment leader interpreted the user input (speech, gestures, and actions) to respond to the user by choosing the relevant remarks from the dialogue model. Certain movements such as cheering or nodding were initiated by the experiment leader by clicking the corresponding button in the WoOz interface. Updating the user model was also done by hand when the user provided new information. Despite the fact that most of the dialogue was scripted in the dialogue model, the experiment leader occasionally had to intervene when the user did something unexpected. If needed, the experiment leader could quickly type a response and have the robot say it via the text-to-speech module.
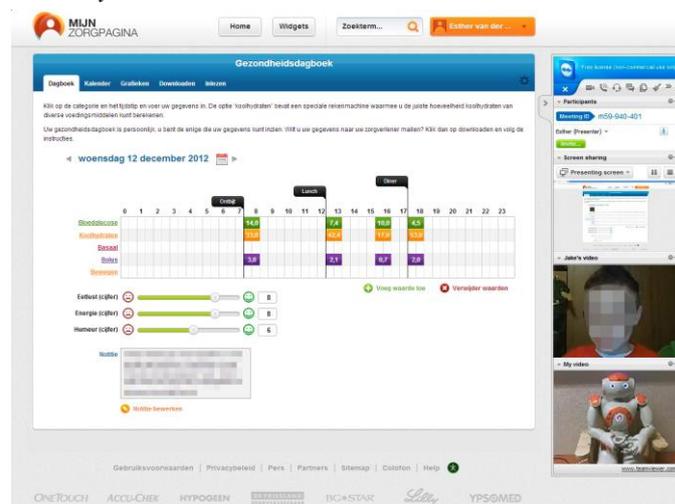
D. Diary

Fig. 2. Screen as seen by the child showing diary and video conferencing software

The study required a diary that allowed the children to not only record their measured values, but that also had room for them to express how they feel. This allows the robot to respond empathetically to the emotional content of the diary. To this end, we chose to adapt an online diary for use in our

experiment. Mijn Zorgpagina (literally 'my care page') is an initiative from Diabetesvereniging Nederland (DVN), the Dutch Association for Diabetes. In cooperation with DVN there were extra sections added to the diary to record the child's emotional well-being. The diary consisted of three different sections (see Figure 2): the 'values' section which consisted of different 'lines' for the recording of blood glucose values, carbohydrate intake, insulin doses and exercise; the 'emotions' section in which the child could rate his/her appetite, energy and mood levels using three sliders; and finally the 'daily activities' section which was a text box in which the children could write anything they wanted to share about their day.

In Figure 2, the video conferencing software (TeamViewer) we used is shown on the right-hand side of the screenshot (face of the child is blurred for privacy reasons). We used TeamViewer to enable desktop-sharing and communication via webcam and audio. Although the children could log into the diary from anywhere, we chose to provide each of them with a laptop that was stripped down to the bare minimum. The main reason for this was that we wanted to make sure all diaries were accessed from the same platform so that there would be no technical difficulties on their end. The children's accounts were set up in a way so that they would automatically log in when there was an internet connection. The child could then invite Charlie for a session. The sessions were all scheduled in advance. If they encountered any issues while attempting to log in or connecting to Charlie, the children could refer back to the child-friendly user manual that we provided.

IV. METHODS

A. Participants

Six children affiliated with Dutch hospital Rivierenland in Tiel participated in the experiment. They were recruited with the help of a diabetes nurse who informed the children and their parents of the experiment. Interested parents were contacted and they received further information. They could then decide whether they still wanted their child to participate. The group consisted of two girls and four boys, aged 9-12 (M=10.8, SD=1.3). All children were diagnosed with diabetes mellitus type 1. On average, they had diabetes for six years. None of the children had any prior experience in keeping a digital diary.

B. Experiment design and procedure

One week before the start of the experiment, we visited each of the children individually at home to introduce them to the robot. We explained the goal of the research and there was an opportunity to ask questions. The robot then introduced itself and asked the child to do the same. After that, we scheduled the sessions with the robot for the following two weeks. Children who forgot their appointments with Charlie were called to remind them. We feared that without reminders, children would forget their study participation, at the cost of valuable data.

The number of participants was small and there was only limited time available for interaction with the robot. Therefore

we decided to do a within-subjects design; this entails that all children kept a diary both with and without the robot. They did this for a total of 11 days. We made two groups of three participants to spread the workload. This means that half of the children started on day 1 and finished on day 11, whereas the other half started on day 2 and finished on day 12. The sessions with and without the robot alternated every day. This excluded the weekends, which were always without the robot because access to the facility where the robot was stored was not possible. The children participated while in the comfort of their own homes using video conferencing software to contact the robot.

C. Measures

Below we present the metrics used for each of the three hypotheses.

1) *Adherence:* In this context adherence is defined as the extent to which children keep an accurate account of their values, mood and activities in their diaries on time (meaning on the same day the values were measured). If the robot has a positive effect on diary adherence, we expect to see 1) more completed diary entries with the robot, and 2) richer diary content (experience sharing/self-disclosure). We determine whether this is true by logging children's use of the diary and comparing the contents of the diary between sessions with and without support from the robot. Furthermore, we measure likeability and trust, because literature found these to be contributing factors for self-disclosure.

2) *Engagement:* An engaged child typically spends more time and is focused on the activity, and takes an active role in the activity. If we measure the time the children spend on their diaries, this tells us something about their level of engagement. Comparing the time spent on the diaries between sessions with and without the robot says something about the influence of the robot on engagement. Active participation and attention are measured by the experiment leader by observing the child's interaction with the robot via the webcam. A child is thought to take an active role in the conversation whenever he/she asks or tells the robot something out of his/her own initiative instead of waiting for the robot to ask something first. We can determine attention by observing the child's gaze direction. When the child looks away from the diary and the robot, he/she is distracted.

3) *Bonding:* A bond between two conversational partners is characterized by emotions such as affection and trust. To investigate to what extent interaction with the robot created a bond, we used a post-condition questionnaire which focused on the degree of relatedness the children experienced with the robot. When a child trusts the robot, believes it has feelings, and thinks that it can truly understand him/her, the feeling of relatedness is strong.

D. Instruments

The children were asked to complete a total of 7 questionnaires. The pre-condition questionnaire was answered prior to the experiment, and inquired about demographic information, interests and expectations. We used this questionnaire to learn more about our participants and whether they understood the experiment correctly. After each interaction session with the robot, the children were again asked to fill in a questionnaire. This questionnaire only contained two questions which inquired about the children's ratings of the robot and the diary. This data can be used to determine whether there are any changes over time. Finally, the children answered a post-condition questionnaire after all the sessions were completed. In this questionnaire we asked them about their overall judgment of the robot and the diary, the degree of relatedness with the robot, and feelings towards the robot. This data was mostly used to determine the extent of the relationship between the child and the robot.

Furthermore, we also made use of three different types of logs. The diary logs were provided by MijnZorgpagina and provided insight into the children's use of the diary on days when the robot was not present. The WoOz logs were automatically generated whenever a command was sent to the robot. We used these to determine use of the diary with the robot. Lastly, the experimenter leader's observation logs were used to note any changes in experience sharing, active participation and attention of the children during the sessions. Miscellaneous observations were also noted in these logs. Table 3 provides a full overview of the measures, instruments and data that were measured.

TABLE I.   OVERVIEW OF MEASURES, INSTRUMENTS AND DATA

Measure	Instrument	Data gathered
Adherence	Pre-condition questionnaire	Demographic information; interest in technology; current diary adherence; expectations of the diary, robot and experiment
	Diary logs	Completed, missing, supplemented and later completed diary entries; characters in daily activity logs
	Interaction session questionnaires	Diary ratings
Engagement	Experiment leader's logs	Active participation, attention
	WoOz logs	Time spent on diary (with robot)
	Diary logs	Time spent on diary (without robot)
Bonding	Interaction session questionnaires	Robot ratings
	Post-condition questionnaire	Robot and diary ratings; degree of relatedness, feelings towards robot
	Experiment leader's logs	Experience sharing

Initially we had planned to record all interaction sessions to carefully note any changes in active participation and attention. However, due to a technical problem, the video conferencing software crashed when the recording software was started. We

came to rely on the experiment leader's observations for data regarding the children's engagement.

E. Setup

Figure 3 provides a schematic overview of the experimental setup. To mimic the natural sitting position of humans during video calls, the robot (1) was seated in a chair during the interaction sessions. The webcam (2) was aimed at the robot from an angle slightly higher than eye level because we wanted the children to believe it was operating its own laptop. During the interaction sessions, the experiment leader (3) was seated out of view. She was in control of the robot's actions using a laptop and an extra screen (4). She was also able to see the screen and webcam of the child using the video conferencing software (5) on a second laptop. The experiment leader made as little noise as possible so as not to alert the child to her presence. To this end, we used a silent mouse (6) that lacked the "click" sound when a button was pressed.
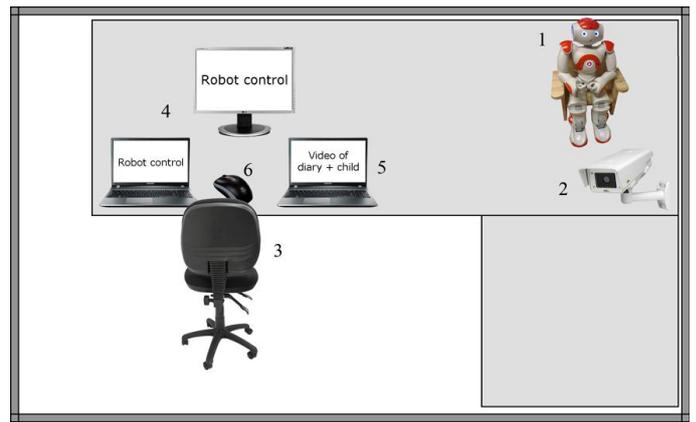

Fig. 3.   Experimental setup

V.   RESULTS

All six children completed the full experiment. Diary adherence prior to the experiment was found to be very low; none of the children kept a diary on a daily basis. Five out of six children used an insulin pump and three of them indicated they did not keep a diabetes diary (anymore) because they were able to read out values from their pumps if needed. Only one child said that he currently kept a diary all by himself, but after enquiring about his diary use he admitted to only doing it once every three months when it was required for a hospital consultation. All of the children said to be at least moderately interested in technological advances such as robots or gadgets.

A. Adherence

The log data from the diary revealed that not all children completed their diaries on time (meaning on the same day the values were measured). When a diary entry was not completed on time, it was usually completed the day after. When they were not interacting with the robot, two of the children sometimes neglected to keep their diary. One of them missed all (6) entries, the other left only 2 entries uncompleted. Three children logged on multiple times (1, 2 and 9 times) to supplement values as new information became available. The

difference between uncompleted diary entries with and without the robot was significant $t(5) = -2.65$, p = .046, but the differences in fully completed $t(5) = 1.63$, p = .165, later completed $t(5) = -1.17$, p = .296 or supplemented entries $t(5) = 1.00$, p = .363 were not. Figure 4 shows the differences in diary completion between conditions.
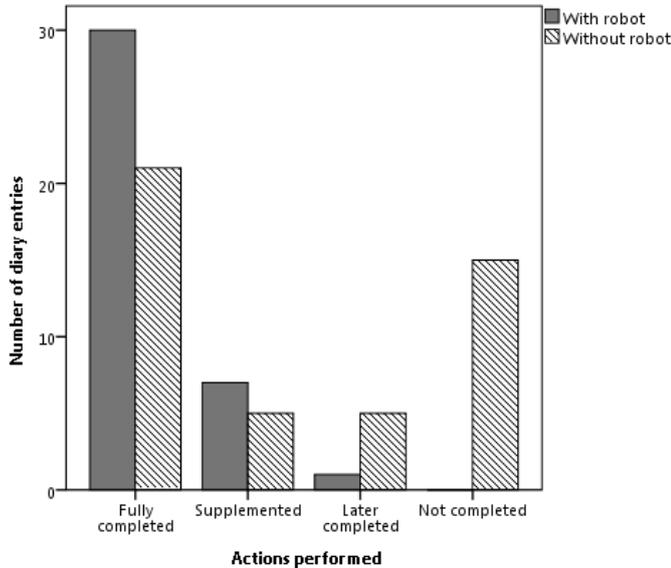

Fig. 4. Diary actions with and without robot

We compared the amount of characters used in the daily activity logs between the days with the robot and without the robot as an indicator for experience sharing. It was found that children wrote significantly more in their logs when they were interacting with the robot (M=83.10, SD=43.96) than without the robot (M=36.8, SD=54.31); t(5)=4.13, p=.009; but there were clear differences between participants. In table 2 it is evident that some participants (5 and 6) always filled in high quantities of data, whereas some others filled in less on days without the robot (2 and 3), or nothing at all when the robot was absent (1 and 4).

TABLE II. TOTAL AMOUNT OF CHARACTERS IN DAILY ACTIVITIES LOGS

Participant	With robot (avg.)	Without robot (avg.)
1	60.4	0
2	36.6	15.7
3	86.4	13.5
4	78.8	0
5	165.6	141
6	70.8	50.8
Mean	**83.1**	**36.8**
SD	**40.13**	**49.58**

Overall, the children rated the diary positive throughout the experiment. The diary received an average rating of 3.9 on a scale from 1 to 5.

B. *Engagement*

We were unable to validate whether there was a difference in the time spent on the diary due to a gap in the log data. The time spent on the daily activities log was not recorded on the days without the robot, so the data from both conditions were unequal. However, we did see how the time spent on the diary changed over time. The first session with the robot typically took between 10 to 15 minutes. But after the second session (at home), the time quickly dropped and stabilized around 5-6 minutes for the later sessions.

The younger children (aged 9) (N=2) were much more open and talkative than the older children (11-12) (N=4). Their answers were longer and their sessions typically took 1-2 minutes longer than those with the older children. They were more likely to ask the robot what it did today, yesterday or last weekend, than the other children were. Older children appeared to be less interested in the robot's life and did not ask it as many questions. They usually answered the robot with a simple "yes" or "no". There was no discernible difference between genders in interaction styles with the robot.

The children appeared to be very patient when they had to wait a while for Charlie to answer. This was apparent in the way that the children remained still and focused even when the robot did not do anything for a while. Overall the children were focused. They did not allow themselves to be distracted by background noises or siblings and focused solely on the diary and to a slightly lesser extent on the robot. When the robot spoke, their attention visibly shifted to the robot for a short while, but then quickly back to the diary. This was apparent from their gaze direction which was visible on webcam.

C. *Bonding*

In the post-condition questionnaire, the children were asked to agree or disagree with a number of statements on a scale of 1 to 5, where 1 meant 'completely disagree' and 5 meant 'completely agree'. Table 3 summarizes the results from the post-condition questionnaire.

TABLE III. POST-CONDITION QUESTIONNAIRE RATINGS

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

The robot received high ratings on all questions. Especially high (average rating above 4) was the rating of the robot's trustworthiness and its human-like behavior. Furthermore, when we asked the children what they liked about Charlie, they said they liked the fact that it asked them questions about the things they did that day, as well as share with them his own daily activities.

We also asked the children how they viewed the robot. Five out of six children chose the option 'Friend'. One child said that Charlie was more like a peer, and another said that it was a device/robot to him (but also a friend). The children rated the robot after every session. On average, the robot received an average rating of 4.2 on a scale of 1 (lowest) through 5 (highest).

Furthermore, we noticed the children often smiled or laughed at the things the robot said, and they waved back to the robot when it greeted them. Overall they were very friendly towards it. The most positive reactions were elicited when the robot immediately responded to the ratings for the emotions and daily activities. The child seemed to think that it really understood him/her. The level of detail in the questions some of the children asked was high, regardless of their age. For example, when Charlie said that it played soccer with friends, they would ask it about the final score and who the goal keeper was. One child even asked about Charlie's birthday, and when it said that was February 2nd, she wished it a happy birthday in advance.

VI. DISCUSSION

A. Self-disclosure and diary use

Children completed their online diary more often when they were keeping it with the robot than when they were keeping it alone. This was to be expected, as the children were actively notified by the experiment leader on the days they were scheduled to fill in the diary with the robot. However, after the children interacted with the robot, they did frequently log in the diary later that day to supplement the diary, on their own initiative. This suggests that the robot was motivational by itself. A critical note with regard to the diary completion is that we called the children who forgot their appointments with Charlie. Considering the small sample size we had, we felt it was more important to have as many interaction sessions as possible to learn what we could about how the robot's self-disclosure influenced diary adherence. Moreover, children consistently filled in more information in their daily activities logs (the bottom part of the diary) when they were keeping their diary with the robot, than when they were keeping it by themselves. Thus, regardless of whether or not the children were reminded of their appointments, when they *did* interact with the robot, they filled in much more information. The self-disclosure of the robot appeared to be a strong motivator for the child to disclose information in return. Therefore, we can confirm the hypothesis that self-disclosure of the robot encourages the child to share more information in his/her diary.

B. Embodiment and children's engagement

From the log data we gathered that the time taken to fill in the diary dramatically decreased after the first two sessions. This can be explained by the fact that during the first session the children listened to the robot explaining every diary section, while in subsequent interactions this explanation was optionally accessible (and rarely asked for). Due to the failed recordings of the sessions, the data on children's interaction behavior was elicited from notes made by the experiment leader during the study. These notes were taken systematically

and were of great use to us for explaining some of the results that we found, but unfortunately they could not be statistically validated. The observations showed a strong difference in active participation between the younger children, who were very open and talkative, and the older children who were less open and talkative. Possibly, the background story for Charlie was not convincing or appealing enough for the older participants in this study. This would be in line with the commentary we received from an older child during the pilot study we performed prior to the experiment ("I think the story is too childish for 11-12 year olds"). Overall, the experiment leader had the impression that the children paid close attention to the robot and the diary. They did not allow themselves to be distracted by background noises, siblings or parents. While some parents chose to supervise their child during the sessions, they did not appear to be a distracting factor. We did however see some mixed results in the answers on the question whether it was difficult to focus when they were keeping a diary with Charlie (in the post-condition questionnaire). But this might also be due to the slow internet connections of some children. Occasionally there would be very large delays in the sound transmission, which made it difficult to understand what Charlie was saying. Since we did not have any data on the child's engagement with the diary without the robot, it is unclear whether it was actually the remote physical presence of the robot that had a positive effect on the child's engagement in the activity. Therefore we cannot confirm the second hypothesis.

C. Robot's empathy and trust and understanding of the children

Overall, the robot was received very well by the children. They greatly enjoyed interacting with Charlie. They believed it had feelings, was able to understand them, and that it behaved human-like, which are signs of empathy. However, we have to be careful in saying the conveyed sense of trust and understanding of the child was purely due to the robot's empathetic behavior (hypothesis 3), because sometimes part of the dialogue was typed by the experiment leader directly and converted to speech by the robot when there was no suitable answer in the dialogue model. As a consequence, sometimes the children were in some way talking to the experiment leader rather than the robot.

D. Future research

There was no explicit feedback about the relationship between blood glucose, mood and daily activities. In future work it would be interesting to add this type of feedback to the dialogue and to discover patterns together with the robot. This brings us to another point of concern: the small talk section of the dialogue model. In the experiment we found that it was difficult to predict the direction of the conversation and adequately reply to the children's questions. Ultimately the goal of the ALIZ-E project is an integrated system which operates without human intervention, so there will need to be some kind of solution for this problem. Furthermore, we chose to do a within-subjects design because we only had limited time and a small number of participants. We feel that in the future it would be wise to repeat the experiment on a larger scale using a between-subjects design to determine whether the

differences we observed were due to the robot's self-disclosure, empathy and physical presence, or whether there is another explanation.

VII. CONCLUSION

This paper investigated the contribution of a social robot to keeping an online diary together with diabetic children. A social robot can enhance the pleasure of the activity, and therefore the motivation of the child. Especially once the robot and the child really get to know each other, the child starts to consider the robot as a friend and he/she really opens up to it. Keeping an online diary together with a social robot can contribute to a better diary adherence. The robot utilizes aspects of physical embodiment, self-disclosure and empathy in its behavior and dialogue to achieve this goal. When we take into account that the diary adherence prior to this study was almost non-existent, this is a considerable improvement. Keeping a record of the values, emotional well-being and the daily activities allows the child to make meaningful inferences about the relationship between these three variables. This positively influences the child's self-reflection capabilities, which in turn contributes to his/her self-management. The robot could help the children overcome the initial hurdles of taking charge of their own diabetes self-management. The addition of a robot does not have to be detrimental to the child's feeling of independence, which becomes increasingly important as they reach puberty. This study provides a sound foundation for future research into robot characteristics and their effect on emotional support for chronically ill children.

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