Effects of Off-Activity Talk in Human-Robot Interaction with Diabetic Children

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***Abstract*— This paper presents the results from an experiment with a conversational human-robot interaction system aimed at long-term support for diabetic children. The system offers a set of activities aimed to help a child to improve its capability to manage diabetes. There is a large body of literature on the techniques that artificial agents can use to establish and maintain long-term social-emotional relationships with their users. The novel aspect in the present study is the inclusion of off-activity talk interspersed within talk pertaining the activity at hand and aimed to elicit the child's self-disclosure. The children in our study (N=20, age 11–14) were more interested to have another session with the robot when their interaction included also off-activity talk, even though there was no difference in the perception of the robot by the children between the groups with and without off-activity talk. Furthermore, individual interactions with the robot positively influenced the children's adherence to a therapy-related requirement, namely the filling in of a nutritional diary.**

I. INTRODUCTION

Children are keen users of new technologies, which can provide interesting opportunities to enrich their experiences, e.g., for educational and therapeutic purposes. In order to make use of this potential, it is necessary to investigate the specific needs of children and develop systems that address them. The work presented here is part of the project ALIZ-E [3] which pursues the goal to develop the theory and practice behind embodied cognitive robots, capable of maintaining believable any-depth affective interactions over an extended and possibly discontinuous period of time, applied to children with metabolic disorders (in particular type I diabetes) [7], [32].

In order to become able to manage their condition themselves, diabetic children need to acquire knowledge about diabetes and suitable healthy nutrition, develop various relevant skills and learn to adhere to the therapy requirements. In the ALIZ-E project we investigate the use of a robotic companion to provide long-term support in this process. We apply the user-centered design paradigm involving close collaboration with caregivers to provide system specifications and testing the system regularly with end users [1].

The system developed in ALIZ-E uses the Nao robot [2] to engage a child in several different activities (cf. §III-E). Since previous research has established that social aspects of interaction are important to sustain long-term engagement of humans with artificial agents, including both virtual characters and robots (cf. §II), the interactions with the ALIZ-E system include both *activity talk*, i.e., conversation pertaining to the activity at hand, and *social talk*, such as greetings and personal introductions.

The novel aspect in the present study is the inclusion of *off-activity talk* (OAT). Interspersed within activity talk, but not pertaining directly to the activity at hand, OAT involves discussion of diabetes- and health-related topics with the aim to elicit talk from the child, in particular, to encourage it to disclose its personal habits and experiences. If successful, OAT could provide a therapeutically valuable instrument to help the doctors and nutritionists to monitor the behaviors of their young patients and hopefully also to motivate the children to adhere to specific therapy-related requirements.

In order to investigate the viability and impact of including OAT in the interactions and to collect empirical data we carried out an experiment during a summer camp for diabetic children. The Nao robot was used during various activities at the camp and interested children had additionally the opportunity to use the ALIZ-E system in individual sessions. In this paper we present first results on the effects of OAT on children's perception of and relationship to the robot, interest in further interaction(s) and adherence to therapy-related requirements, namely the filling of a nutritional diary during the summer camp.

II. BACKGROUND

Voluntary long-term use is required in many applications in, e.g., healthcare, education, entertainment, as a prerequisite for other system objectives [10]. Bickmore and his team coined the term *relational agents* for computational artifacts designed to establish and maintain long-term social-emotional relationships with their users and presented a thorough overview of techniques for constructing, maintaining, and evaluating such relationships, based on research in social psychology, sociolinguistics, communication and other social sciences [11]. The team carried out numerous studies to evaluate the effects of various aspects of (virtual) agent behavior on long-term engagement, e.g., [10].

Relational behavior strategies are also investigated in human-robot interaction. Examples involve robots as companions [29], [13], [5] or in therapeutic and educational settings[22]. In these studies the importance of different characteristics like personality, the ability of long term interaction linked to engagement and a proper combination of verbal and non-verbal cues has been highlighted as key determinants towards a human-robot interaction capable not only of entertainment but also to provide the end users support

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and motivation in various aspects of their lives. Studies have demonstrated the importance of human-like communication rather than appearance [32], [14]. It is often underlined that to build long-term bonds with (young) users, a robot needs to be able to sustain social dialogues, including abilities like initial greetings, chatting, and expressing personal opinions and beliefs [17]. Initial greeting, in particular, is a social skill which [21] considered one of the eight most important design patterns in human robot interaction. Moreover self-disclosure and empathy can contribute to familiarity between two agents engaged in a conversation [33], [30].

Social dialogue is included as one of the very important abilities of relational agents in the studies, e.g., [11], [17]. The social dialogue planner proposed in [8] was the first to use an explicit dynamically updated model of the agent-user relationship. It was designed to sequence agent task and social utterances to satisfy both task and relational constraints. Several other agents which make use of social dialogue (small talk) have been developed to date, using hand-crafted strategies (cf. [24] for an overview). [24] pioneered the use of a functionally-motivated taxonomy of small talk dialogue acts based on the social science theory of face and extracted dialogue act sequences for social talk from an annotated corpus. [5] on the other hand, analysed a corpus of child-adult conversations to extract so-called personalization behaviors. They identified strategies for gathering and exploitation of personal information (e.g. family, friends, pets); preferences (e.g. favorite movie, favorite food); agenda (plays football on Saturday, has maths every Thursday); activity-specific information (preferred stories, current level of quiz difficulty); interaction environment (e.g. time, day, season, weather).

The off-activity talk we incorporate into our system differs from social talk (small talk) in that its purpose is to encourage the child's self-disclosure on topics in the domain of diabetes- and health-related concepts. The system thus should behave as a *listening agent* [15]. Previous work on listening agents examined how listening-oriented dialogue differs from casual conversation in terms of dialogue act distribution [15] and addressed the generation of appropriate verbal and non-verbal behavior while listening [37].

Entertainment and companionship are important, but typically not the primary objectives of a system in the area of healthcare or education. There is growing body of research on systems to interview patients and consumers about their health and provide health information and counseling using natural language dialog (cf. [9] for an extensive overview). Recent work includes the use of robots to motivate children and/or students to study [22], to manage physical activity [18] or diet [23]. In ALIZ-E studies have been carried out on the use of a robot to motivate children to learn [19] and to manage their diabetes [32]. Building motivation for therapy adherence is an issue of paramount importance with children with chronic diseases [28].

III. GOALS AND METHODOLOGY

A. Goals

The experiment had a twofold aim: (i) investigate the effect of including OAT in the child-robot interaction in the system; (ii) collect empirical data for qualitative analysis of OAT interactions to support further system development. In this paper we concentrate on the former and in particular on the following three aspects of the children's attitudes:

1) perception of the robot and the relationship
2) interest to have further interaction(s) with the robot
3) adherence to filling in a nutritional diabetic diary

Each of these constitutes a dependent variable in the study.

B. Measures

The perception of the robot by the child is measured through two specific questionnaires: One is a questionnaire for self-assessment of the child's engagement and relationship to the robot, and its opinions about the robot and the interaction, composed of seven-point Likert scale assessments relative to the impression of the Nao the child develops during the game activities. It was designed to explore the feelings of the child during the interactions, what they thought about the game played, their mood during the interaction, and also their interest to play again with the robot [12]. The other questionnaire elaborates on the child's perception of the robot by a multiple-adjective choice to describe Naos characteristics. There are in total 24 adjectives, e.g., beautiful, funny, tender, intrusive, boring, ... The child is asked to select three that fit best. The questionnaires have been carefully designed to minimize the risk of a ceiling effect in the responses.

The interest of a child to have further interaction(s) with the robot is derived from a cross-check between the intention expressed by the child to play again in the questionnaire and the fact whether s/he actually asked the staff to schedule another session with the robot during the summer camp.

Finally, nutritional diary-filling adherence is measured by checking whether the child filled in the diary at least once for one of the daily meals over three consecutive days. The reason for defining the threshold so low is that hardly any child ever filled in the diary at all.

C. Design

The study had three conditions in a between-subjects design:

- In the OAT condition, the child had an individual interaction with the robot including OAT sub-dialogues.
- In the NOAT condition the child had an individual interaction with the robot without OAT.
- The CONTROL group had no individual interaction with the robot.

In all conditions the children participated in the usual activities during the summer camp, attended lessons and had sessions with doctors and a nutritionist. As part of the therapy they were all asked to fill in the diabetic nutritional diary with details on their meals for three days during the camp. They

Group	Female	Male	Total
OAT condition	5	6	11
NOAT condition	5	5	10
CONTROL	11	27	38

TABLE I
EXPERIMENT GROUP SIZE AND GENDER DISTRIBUTION

were also all exposed to the robot during various educational and recreational activities at the summer camp.

Subjects in the OAT and NOAT group in addition had an individual session with the robot. In both conditions the robot at some point during the session mentioned the filling in of the diary. In the OAT condition the robot initiated an OAT sub-dialogue at various points during the session (cf. §III-F).

D. Participants

The experiment took place on nine days in August 2013 at the summer camp for diabetic children in Misano Adriatico, a seaside location in Italy. These camps are organized annually by the Italian patients association Sostegno70 [4] in strict collaboration with the Center for Pediatric and Adolescent Endocrinology of San Raffaele Hospital, Milan (Italy). They have both educational and therapeutic aims and are a fundamental tool in the educational process of diabetic children.

At the beginning of the summer camp the children were invited to take part in the experiment. Their relatives (or legal tutors) received and signed an informed consent for the participation in the proposed activities.

Among the children attending the camp 59 (age 11–14) were involved in the present study. 21 of them volunteered to participate in the individual session(s) with Nao. They were randomly assigned to one of the two intervention conditions, OAT vs. NOAT. Tab. I shows the details of the groups.

E. Procedure

Children who volunteered for the intervention were given appointments for their individual session with the robot, in their spare time throughout the day. They were instructed about the activities available with the Nao and that they may choose freely between them.

The available activities were: (i) the Quiz activity, in which the child and the robot ask each other series of multiple-choice quiz questions from various domains [26], [25], [27]; (ii) the Sandtray, which is an activity where the robot and the child solve sorting tasks on a shared touch-table [6]; (iii) the Dance activity where the robot explores various moves with the child, making a connection between motions and nutritional concepts [35], [34]. The Quiz was always played first and then the child could freely switch among all three available activities.

The child could end the interaction at any point, or continue up to a maximum duration of 30 minutes. After the interaction a staff member administered the questionnaires and debriefed the child. Fig. 1 shows children performing the activities and the room with the experimental setup.

The interactions were carried out using the ALIZ-E system in a partial Wizard-of-Oz setup. The Wizard simulated the recognition and interpretation of the user's speech and for OAT also the next system action. The next system action in the Quiz, Dance and SandTray activity was selected and verbalized automatically, while the Wizard had the possibility to override the automatic selection if needed. Spoken output was synthesized using Mary TTS [36] with an italian voice developed in the project [26]. Spoken output verbalization was designed so as to ensure high degree of variation in the system output [26].

F. Off-activity talk

In strict collaboration with a psychologist of the San Raffaele Hospital we defined the OAT topics listed below:

- Hobbies: typical day; activities in spare time
- Diabetes: checking glycemia; checking insulin; injections; hypoglycemia
- Nutrition: eating habits; food choices
- Friends: discussions about diabetes; handling diabetes when with friends
- Adults: behavior w.r.t. diabetes; advice
- Nutritional diary: function; filling in; motivation

We formulated system utterances for these topics (several per topic) and implemented them as canned text in the system. To elicit OAT on a given topic the system might for example say:

- Hobbies: *What do you like to do in your spare time?* or *Do you do any sport or another activity?*
- Diabetes: *Do you inject insulin yourself?* or *If your glycemia is low, what do you do?*
- Nutrition: *How often do you eat fruit and vegetables?* or *What are you favorite foods?*
- Friends: *Do your friends know about diabetes?* or *When you go out, do you take your glucometer and insulin?*
- Adults: *How do your parents behave with you with respect to diabetes?*
- Nutritional diary: *Can you explain to me how the diary works?* or *Is it difficult to fill in the diary?* or *I guess it's difficult but it is very important and useful to do so.*

The filling in of the nutritional diary was mentioned in both conditions. In the NOAT condition this was a single mention (i.e., *I know you have to fill out a nutritional diary, do you want to tell me something about it?*), while the OAT condition involved further elaboration on the diary topic concerning completion of and motivation for the filling in of the diary as illustrated above.

OAT is triggered by the robot at various points during the activities. In Quiz this is between question-answer sequences. The first step to start OAT is to say something to "escape" from the Quiz talk, e.g., *Now, I am curious about something.* The next step is to raise one of the topics as illustrated above. OAT on a given topic can continue by additional utterances in order to create a more complex extended sub-dialogue. Finally, the Quiz activity is resumed by saying, e.g., *OK, now let's do another quiz question.*

Fig. 1. Left to right: The experimental setup during the summer camp and children engaged in activities with the ALIZ-E system: dance, quiz, sandtray. (anonymized)

In SandTray OAT about nutritional habits is triggered while the child is playing a virtual game about the food and carbohydrates. In Dance several OAT utterances are interlaced with the sequence of movements and sounds, and triggered when the robot begins to explain the related nutritional concepts.

G. Hypotheses

Based on the findings in the literature about what contributes to engagement and may motivate adherence, we expected that OAT would have a positive influence. We hypothesized that subjects in the OAT condition would score higher than those in the NOAT condition on all measures listed in §III-B, and that subjects in the OAT and NOAT conditions combined would score higher than those in the CONTROL group on diary-filling adherence.

IV. RESULTS

A. Perception of the robot and the relationship

To analyze the results of the first questionnaire, we calculated the mean and standard deviation of the corresponding scores on the Likert scale for each question. The means were higher in the OAT condition on almost all questions. However, a comparison of two means test (t-test double tailed) between the means corresponding to the same questions in the OAT and NOAT condition revealed no statistical significance.

A comparison of the adjective choices in the second questionnaire did not reveal any differences between the OAT vs. NOAT condition either. In fact, the number of times a particular adjective was selected was never high enough to characterize either the OAT or the NOAT condition.

None of the negative adjectives (pretended, simple, frail, stupid, complex, boring, intrusive and bad) were selected by any subject in either condition.

B. Interest to have further interaction(s)

All 21 subjects in both OAT and NOAT condition responded positively to the question "Do you want to play again with Nao" in the questionnaire. However, only 11 actually booked a subsequent time slot for playing again during the summer camp. Tab. II shows the distribution.[1]

Group	Proportion	Mean	St. Dev.
OAT	9/10	0.9	0.32
NOAT	2/10	0.2	0.42

TABLE II

BOOKING ANOTHER SESSION WITH THE ROBOT

Group	Proportion	Mean	St. Dev.
OAT + NOAT	8/20	1.4	0.5
CONTROL	4/38	0.1	0.31

TABLE III

FILLING IN THE NUTRITIONAL DIARY

The reported standard deviations are very high but this can be explained because of the limited variability of the indicator with which we have chosen to indicate the actual booking request (1), and only the intention (0). Double tailed t test reveals strong statistical significance (t=4.2, p=0.0006).

C. Adherence to filling in the nutritional diary

The number of subjects who filled the nutritional diary at least once during the summer camp was exactly the same 4/10 in both the OAT and NOAT condition (t=0.00, p=1.00).[2]

A comparison of the results from the OAT and NOAT groups combined against the CONTROL group reveals an effect of the individual interaction with the robot. The distribution is shown in Tab. III (value "2" was used to represent the case diary filling and value "1" the lack of diary filling). A double tailed t test comparing the two means confirmed statistical significance (t=2.39 with p=0.0103).

Also in this case the high value of the standard deviations can be explained with the limited variability of the indicators chosen for the analysis (values 1 and 2).

We double-checked whether it is justified to attribute the increased adherence to the individual interaction with the robot by checking the dates on which the children filled in the diary. For 4/8 (2/4 in each condition) we could establish that they filled in the diary after the session with the robot. The entry date was missing for the others.

[1]We excluded one subject in the OAT condition from the analysis, because he played with the Nao for the first time on the last day of the camp, and thus could not actually book another appointment.

[2]We again excluded the one subject who played on the last day. His interaction with Nao could not influence his behavior during the summer camp.

V. DISCUSSION

A. Perception of the robot and the relationship

The analysis of the questionnaire results did not show any difference between the OAT and NOAT condition regarding the children's perception of the robot and the relationship.

We can only suggest qualitative assessment differences based on the questionnaire answers, even if they did not show statistical significance. Most of the questions related to the affective sphere of emotions suggest that OAT might have a positive effect on the children's perception of the robot. The fact that Nao asks questions to the child on various topics and shows interest can trigger a feeling of affection that pushes the child to see Nao as a friend who cares about his/her health status. Perceiving Nao as a friend in the OAT condition may put the child at ease, so that it feels free and confident to choose whatever s/he likes among the activities of the ALIZ-E system and to vary them to his/her interest. This interpretation of the results is corroborated by the observation that neither in the OAT nor in the NOAT condition negative adjectives are used to describe Nao. In particular, it is noteworthy that the robot is not perceived as intrusive or curious in a negative way in the OAT condition..

One caveat concerning the Likert-scale questionnaire is that it does not contain any items designed specifically to target the potential effects of OAT. This is something to consider in future work.

B. Interest to have further interaction(s)

The study shows that the children in the OAT group are significantly more likely to be interested to play with the robot again. This increased level of engagement may be due to the perception of a more rich interaction and more similar to that among humans, in particular friends, as observed above and supported also in [16], [20], despite the fact that no differences in perception of the robot were measured between the conditions.

Another way to investigate the children's engagement is to analyze the length of their interactions with the system. It is for this purpose that we designed the study so that the child could freely end or continue the interaction. The corresponding analysis however requires a more precise measurement than just the time the child spends interacting with the robot, as we for example need to subtract delays due to slow responses of the wizard or technical problems. It also appears sensible to count dialogue or game turns. This necessitates further processing of the collected data which we plan to carry out in the near future.

The current study did not involve multiple sessions of the child with the robot. We have performed a longitudinal study with the ALIZ-E system in the past, where children came to the San Raffaele Hospital for three separate sessions on different days at least week apart [32], [31].

C. Adherence to filling in the nutritional diary

The study reveals a stronger adherence to the requirement of filling in the nutritional diary as a consequence of individual interactions with the robot, in comparison to a control group without individual interactions. We attribute this result to the fact that the individual interactions contained an allusion to the compilation of the diary in both conditions. This common feature has led to a general understanding of the message, event without the additional diary-related OAT. This is why the OAT did not have any effect on this measure.

Previous work contains examples where a positive effect on long-term engagement couples with no effect on or even with an adverse correlation with behavior change [10]. In our study we observe that the effect on engagement across multiple sessions aligns with the effect on the behavioral measure (adherence). This cannot yet be taken to disprove the earlier findings, in particular because of the still very short time-span of the intervention in our study, and thus the possibility that the effect on adherence might wear off. Further investigation of the effects in longitudinal studies is clearly needed.

VI. CONCLUSIONS

We described an experiment with a conversational child-robot interaction system designed for the purpose of long-term support of diabetic children. The experiment was conducted in order to investigate the viability and impact of enriching the interactions with off-activity talk aimed to encourage the child's self-disclosure about its habits and experiences concerning diabetes and health-related topics. If off-activity talk proves effective, it could become a useful tool for doctors and caregivers to monitor their patients' behaviors and to contribute to their motivation.

We presented first results on the effects of off-activity talk as outcomes of the experiment: (1) We found no effect of off-activity talk on children's perception of and relationship to the robot in comparison to interactions without off-activity talk, although we have qualitative evidence that off-activity contributes to a positive perception of the robot as a friend. (2) We found a higher children's interest to engage in further interaction(s) with the robot after interactions with off-activity talk then after interactions without off-activity talk. (3) We found no effect of off-activity talk on adherence to filling in a nutritional diary during the summer camp in comparison to interactions without off-activity talk; however, we found a positive effect of individual interactions with the robot. From a qualitative point of view, this is outcome is reinforced by the investigation of the children's engagement in the interactions. The presence of off-activity talk has a clear impact on their desire to play again with the robot, which can be used to foster long-term interactions. We conclude that it is worth-while to include off-activity talk in systems like the ALIZ-E one.

Our plans for near future work include analysis of the length of the interactions as another way of trying to assess the effect of off-activity talk on engagement; analysis of off-activity talk interaction patterns, focusing on the children's responses; modeling and processing of off-activity talk for autonomous child-robot interaction; investigation of off-activity talk in longitudinal studies.

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