Analysis of the Responses to System-Initiated Off-Activity Talk in Human-Robot Interaction with Diabetic Children*

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Abstract

We carried out an exploratory WOZ study with a conversational human-robot interaction system which offers a set of activities aimed to help a child to improve its capability to manage diabetes. The novel aspect is the inclusion of robot-initiated *off-activity talk* (OAT) on diabetes- and health-related topics. We present an analysis of the OAT sub-dialogues: their distribution, the prompts, children's responses, engagement. Children generally engaged well. They sometimes also reciprocated the robot's topics and even took initiative with new ones. On the other hand, we observed a decline in children's engagement as the interactions progressed. We attribute this mostly to the delays in system response, due to the WOZ setup.

1 Introduction

The work presented here is part of the ALIZ-E project (Aliz-E, 2014). We investigate the use of a robotic companion to provide support to diabetic children, who need to acquire knowledge about diabetes and suitable healthy nutrition, develop various relevant skills and learn to adhere to the therapy requirements, in order to become able to manage their condition themselves (Nalin et al., 2012; Belpaeme et al., 2013).

The system developed in ALIZ-E uses the Nao robot (Aldebaran, 2014) to engage a child in several different activities (cf. §3). 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. §2), 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.

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The novel aspect in the present explorative 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 disclosure of personal habits and experiences. If successful, OAT could provide a therapeutically valuable instrument to help the doctors and nutritionists to monitor the children's behaviors and hopefully also to motivate the children to adhere to specific therapy-related requirements.

To investigate the viability and impact of OAT and collect empirical data we carried out an experiment during a summer camp for diabetic children (cf. §3). In (Kruijff-Korbayová et al., 2014) we describe the experiment in detail and preent an analysis of children's perception of and relationship to the robot, interest in further interaction(s) and adherence to therapy-related requirements, namely filling a nutritional diary during the summer camp. In the present paper we focus on OAT: its design (§4) and the experience with it (§5 and §6).

2 Background

(Bickmore and Picard, 2005) coined the term *relational agents* for computational artifacts designed to establish and maintain long-term social-emotional relationships with their users. Their team carried out numerous pioneering studies to evaluate the effects of various aspects of (virtual) agent behavior on long-term engagement, e.g., (Bickmore et al., 2010). Relational behavior strategies are also investigated in human-robot interaction, e.g., robots as companions (Lee et al., 2006; Chidambaram et al., 2012; Adam et al., 2010; Nalin et al., 2012) or in therapeutic and educational settings (Kanda et al., 2004; Dautenhahn et al., 2005; Kidd and Breazeal, 2007; Fasola and Mataric, 2012).

It is often underlined that to build long-term

bonds with (young) users and provide them support and motivation, a robot needs to be able to sustain *social dialogues*, including abilities like initial greetings, chatting, and expressing personal opinions and beliefs (Higashinaka et al., 2010). Initial greeting, in particular, is a social skill which (Kahn et al., 2008) 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 (Reis and Shaver, 1998; Moon, 2000).

(Bickmore and Cassell, 2001) were the first to use an explicit dynamically updated model of the agent-user relationship. Their social dialogue planner was designed to sequence agent task and small talk utterances to satisfy both task and relational constraints. Several other virtual agents with hand-crafted small talk dialogue strategies are overviewed in (Klüwer, 2011), who proposes 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. (Adam et al., 2010) on the other hand, analyzed 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).

Small talk is similar in structure to OAT. However, OAT has the purpose to encourage the child's self-disclosure on topics in the domain of diabetes- and health-related concepts. In the area of healthcare and 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 (Bickmore and Giorgino, 2006). Such dialogues have similar content as OAT. In our system we are using game-like activities as a context within which OAT takes place.

3 Experiment

The data analyzed in this paper was collected during the experimental activities described in detail in (Kruijff-Korbayová et al., 2014), carried out in August 2013 at a Summer Camp for diabetic children organized in Misano Adriatico (Italy) by the Center for Pediatric and Adolescent Endocrinology of San Raffaele Hospital (Milan) in cooperation with the Italian patients association SOStegno70 (Sostegno70, 2014).

3.1 Participants

In total 62 children (age 11-14) attended the summer camp and were exposed to the Nao robot (Aldebaran, 2014) during various joint activities. 24 children volunteered to participate in individual session(s) with the robot. 13 of them (7 male, 6 female) were randomly assigned to the OAT condition of interaction. In this paper we analyze the dialogue data collected with these children.

3.2 System

The interactions were carried out using the system developed in the ALIZ-E project (Belpaeme et al., 2013), in a partial Wizard-of-Oz setup. The following activities were available: (i) Quiz, in which the child and the robot ask each other series of multiple-choice quiz questions from various domains (Kruijff-Korbayová et al., 2012a); (ii) SandTray, where the robot and the child solve sorting tasks on a shared touch-table (Baxter et al., 2012); (iii) Dance, where the robot explores various moves with the child, making a connection between motions and nutritional concepts (Ros et al., 2011; Ros et al., 2014). Fig. 1 shows children performing the activities and the room with the experimental setup.

One and the same wizard operated the system in all interactions, and was supervised by a psychologist. The wizard simulated the recognition and interpretation of the user's speech[1] and for OAT also the next system action selection. We provided an interface for the wizard to trigger OAT: The wizard thus could select an OAT dialogue move as the next system action from a set of given options at any point during an activity. The verbalization was done automatically or the wizard could type something in on the fly. 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 (Schröder and Trouvain, 2003) with

[1] We did not introduce any noise into the child input to simulate speech recognition errors in this experiment.

Figure 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)

an italian voice developed in the project (Kruijff-Korbayová et al., 2012b). Spoken output verbalization was designed so as to ensure high degree of variation in the system output (Kruijff-Korbayová et al., 2012b).

3.3 Procedure

Each volunteer child had a scheduled appointment in their spare time during the day. Before the session, the child was informed about the experiment, instructed about the system and the available activities and filled in a demographic questionnaire.

After this initial phase the interaction started. The robot introduced itself with its name, and asked the name of the child. It then explained the rules and they started to play, first the Quiz game. The children were then free to switch between the three activities and to stop the game at any time. If not previously interrupetd by the child, the session ended after 30 minutes of continuous interaction.

After the interaction, the child was debriefed and could make an appointment for another session with the robot.

We made video and separate audio recordings.

4 Off-Activity Talk Design

The following OAT topics were defined in strict collaboration with a psychologist of the San Raffaele Hospital:

- 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 several OAT prompts for each topic and implemented them as canned text utterances in the system, as illustrated below:

- 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.*

In Quiz OAT is triggered between question-answer sequences. The first step for the robot 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 explicitly by saying, e.g., *OK, now let's do another quiz question.*

In Dance we defined several OAT utterances to be interlaced with the sequence of movements and sounds, and triggered when the robot begins to explain the related nutritional concepts. Similarly to Quiz, the Dance activity would be explicitly interupted for OAT and resumed afterwards.

In SandTray OAT about nutritional habits can be triggered while the child is playing a sorting game about food and carbohydrates. The game structure makes it easy to raise OAT topics related to the object shown on the tablet, e.g. asking *What food do you prefer between these?* or *Is there any food among these that you put in your food diary?*. OAT thus usually does not need to interrupt the SandTray activity, and there usually need not be an "escape" turn like in Quiz. Consequently, it is also not necessary to explicitly resume the activity.

ID	#topics	#subdial.	#turns R	#turns C	#init. C
02	3	12	33	35	4
04	3	3	25	26	4
05	4	8	25	23	1
09	4	11	20	20	1
10	2	4	22	22	-
11	5	13	25	22	1
12	5	12	24	21	2
14	3	7	16	7	-
17	2	3	19	18	4
18	3	9	25	21	-
19	1	3	7	4	-
22	2	5	17	15	2
24	4	13	37	25	-

Table 1: Distribution of OAT topics, subdialogues, robot and child turns and child initiative, per child

The wizard was instructed to first let the child get familiar with the interaction with the robot by doing the Quiz activity. OAT was thus not triggered immediately at the beginning. The wizard was free to decide when to continue pursuing an OAT topic, address a new one or return to the main activity (also upon request from the child). Concerning the OAT topic selection, the wizard was instructed to always raise the issue of the diabetic diary function (but not necessarily as the first theme). When possible, the wizard should prefer OAT topics related to the current semantic content in the ongoing activity (e.g., related to the content of a question in Quiz or to the objects being sorted in SandTray).

5 Off-Activity Talk Analysis

We collected a total of 102 OAT subdialogues. We defined an OAT *subdialogue* as the chunk of interaction around one OAT *topic prompt* by the robot, i.e., the robot raising an OAT topic. An OAT subdialogue ends either by a return to the current activity or by another robot's OAT prompt (typically on a related topic). In other words, we count the robot's OAT prompts. (1) shows a slightly modified excerpt for illustration. It contains two OAT subdialogues: (1a)–(1h) and (1i)–(1n), around the OAT prompts in (1c) and (1k), respectively.

(1)
a. R I'm curious.
b. C Tell me.
c. R Do you check glycemia yourself at home?
d. C Yes, yes,
e. C I'm doing it all by myself.
f. C My parents don't check me, practically never.
g. R Very good.
h. C Thanks.
i. R May I ask more?
j. C Sure. Say all you want.
k. R Do you realize when your blood sugar drops?
l. C Yes, always.
m. C Do you want to tell me anything else?
n. R Not now, maybe later.

OAT subdialogues vary in length, from 2 to 16 turns. There were in total 209 robot and 194 children turns. Tab. 1 shows basic distribution data.

The number of robot and child turns was usually balanced, although there are a few children who were reluctant to respond and show considerably fewer turns than the robot. While most of the children's turns are responses to the robot's OAT inititative, the children sometimes took initiative, too. We will return to this in more detail in §5.3.

5.1 OAT Prompting

The robot raised between 1 and 5 OAT topics per child. The number of OAT subdialogues varied considerably, between 3 and 13.

When preparing the experiment, we expected that the OAT prompt would typically pick up a *contextual topic*, i.e., a topic already present in the context of the current activity. (2) illustrates this: after a nutrition Quiz question involving vegetables in (2a), a nutrition OAT is initiated about eating habits concerning vegetables in (2d).

(2)
a. R Now let's talk about nutrition. What are the best months to eat fresh broccoli?
b. C From June to September.
c. R No, that's wrong. From September to March.
d. R Do you like vegetables?
e. C Not that much.
f. R Which are your favorite foods?
g. C There are a couple - say, pizza.
h. R Yummy.

This was less frequent than we had envisaged (cf. Tab. 2). Among the 56 OAT prompts issued during an activity, only 15 address a contextual topic, whereas 41 address a non-contextual topic.

The remaining 46 prompts are instances of OAT *topic continuation*: an OAT topic is elaborated upon in a sequence of subdialogues. Typically, another facet of a topic is addressed in a continuation. For example, the function of the diary is addressed first, and then the difficulties in filling it in; or a subdialogue about glycemia is followed by one about insulin injections, thus elaborating on the diabetes topic. The OAT prompt (1k) illustrates continuation on the diabetes topic, prompt (2f) a continuation on nutrition.

Relation	Quiz	SandTray	Dance	Total
contextual	5	10	-	15
non contextual	18	21	2	41
continuation	18	25	3	46
Total				102

Table 2: Relation of OAT topic to context

Topic	# no cont.	# cont.	# subdialogues
Hobbies	7	3	3
Diabetes	10	7	11
Nutrition	20	12	14
Friends	2	0	0
Adults	2	0	1
Diary	28	9	17

Table 3: Frequency of topic continuation and number of subdialogues per topic.

Tab. 2 also shows that contextual topics are relatively more frequent in SandTray than in Quiz, and absent in Dance.

Tab. 3 shows how often the addressed OAT topics were continued and the number of subdialogues per topic. The length of single topic chains varies from usually 1 to 3 subdialogues; only in one case the Diabetes topic was elaborated in 4 subdialogues, prompting the subtopics glycemia, insuline injections and injection places.

Tab. 4 shows the frequency of raising the various OAT topics, and also the distribution of OAT topics across the activities. Recall that Quiz was the first activity for each child and that the diary topic should always be raised. It is therefore not surprising that the diary topic is most often raised during Quiz. Quiz is also where the diabetes topic is raised most often. Nutrition, on the other hand, is most often raised in SandTray. This is because questions about food choices and preferences fit well into the context when the child is sorting edible items. That is also why we find more contextual topics here.

OAT was triggered only in very few cases during Dance, mostly raising non-contextual topics. Just in two cases a previous topic was continued: as a child didn't understand a question about the diary during the Quiz game, the topic was raised again during Dance (*I'm curious. We were talking about the food diary. Do you remember to fill it in?*) and again continued in a second subdialogue. In another case, the Dance activity concluded with a Diary reminder.

Although the diary topic was in a sense obligatory, there are only 4 cases where it is raised as the first OAT topic. Hobbies, diabetes and nutrition were the other topics raised first.

Topic	# Subtopics	Quiz	SandTray	Dance
Hobbies	10	0	7	3
Diabetes	17	12	5	0
Nutrition	31	2	28	1
Friends	2	0	2	0
Adults	2	0	2	0
Diary	37	20	13	4
Other	3	0	3	0

Table 4: Frequency and distribution of OAT topics

Topic	Pos.	Neg.	Short	Full	Elab	None
Hobbies	1	-	6	1	2	-
Diabetes	6	-	4	5	2	-
Nutrition	10	4	5	8	2	2
Friends	2	-	-	-	-	-
Adults	1	-	-	1	-	-
Diary	10	2	5	7	9	4
Other	-	1	-	-	-	2

Table 5: Form of children's responses

5.2 Childrens' Responses to OAT Prompts

Tab. 5 shows the distribution of children's responses to OAT prompts. First of all, the children mostly did respond. We shall say more about engagement in §5.4, here we concentrate on the surface form and content of the responses.

Brief responses prevail, including yes/no and their equivalents (cf. (1d)) and short responses (typically phrases), e.g., naming a food. This reflects the fact that OAT prompts were most often formulated as closed questions, allowing such short answers (e.g., (1c), (1k) again). Nevertheless, full-sentence responses such as (1e) are as frequent as short-phrase ones, and have a similar distribution across topics. There is of course variation across children: some gave no full response whereas others gave a few. Moreover, children seem to give more detailed answers during Quiz than during the SandTray activity; maybe because Quiz is actually *interrupted* by the OAT prompt, while SandTray usually goes on in parallel.[2]

On the other hand, the instances where children elaborated on their response, as in (1f) for example, are fewer and not equally distributed: most occurred in response to the general prompt about the diary topic, shown in (3).

(3) R I know Gabriella gave you a food diary to fill in, it is very interesting. Would you explain to me how it works?

[2] In some cases the child's answer is even interrupted by the game-related feedback.

i. C1 Yes. You enter the meals you eat and the blood sugar before and after eating.

ii. C2 No - I don't remember myself so well how to fill it in.

(3i) exemplifies a positive elaborated answer. However, most of the other elaborations on this topic were indications of problems, e.g., the child did not know how to fill in the diary, as in (3ii), or has not yet received it.

5.3 Childrens' OAT Initiative-Taking

We were delighted to observe that the children sometimes grabbed the initiative and raised an OAT topic themselves. It happened in 20 subdialogues, which we consider a high occurrence compared with the 102 robot's OAT subdialogues.

In 17/20 cases the child asked something about the robot. Most frequent (10/17) was *reciprocation* of OAT topics, such as nutrition, e.g., asking whether the robot also likes a given food (3); what it's favorite food is (2); how often it eats fruit (1); or hobbies, e.g., what the robot does in spare time (2); whether it does any sport (1); whether it likes a given sport (1). In the other cases (7/17) the child brought up a *new topic*: what is the robot's name (1)[3]; how old it is (1); does the robot have diabetes (2); why would it need a diary (1); why should it be afraid of needles (1); how does it know how cheese tastes (1). A new topic was sometimes brought up out of the blue and sometimes as the child's follow-up to something the robot said.

In the 3/20 cases where the child's initiative was not asking something about the robot, the child asked whether the robot wanted to discuss any other topic (1); requested an explanation of the diary function (1); and disputed whether pizza was a good food choice (1).

5.4 Engagement

As already said, children mostly did respond to the OAT prompts. Moreover, noone ever turned down an explicit OAT-permission check, such as that in (1a) or (1i). Not surprisingly, there are individual differences between children in terms of how readily they engage in OAT. There are many instances of OAT where the children engage very naturally, respond friendly and elaborate, reciprocate, and even take the initiative, as discussed above. But there are also cases like (4) where there appears to be reluctance, the responses are terse, and the child may request to return to the main activity.

(4) a. R Do you like dancing?
b. C Yes.
c. R Same here.
d. C Shall we play another game?

Only one child very much resisted engagement in OAT altogether. His responses were inaudible, mono-syllabic or simply absent (cf. (5c)–(5f)):

(5) a. R What's the weirdest food you've ever tried?
b. C Hot dog.
c. R Is it good?
d. R What are your favorite foods?
e. R I know Gabriella gave you a food diary to fill in, it is very interesting. Would you explain to me how it works?
f. R If you don't want, doesn't matter. Just remember to fill it in, it's important.
g. C Okay.
h. R Is there something you'd like to ask me?
i. C No.
j. R Okay.

We carried out an annotation of engagement: 3 annotators (native speakers of Italian, 2 of the authors and the psychologist who was involved in the experiment) annotated every OAT subdialogue on a 5-point scale: 1 - passive, uninterested (not participating); 2 - annoyed; 3 - courteus, neutral; 4 - interested; 5 - very interested.

To measure inter-rater agreement, we computed Kendall's *W*. It was quite high at a value of 0.87. The annotators reported that the most important factors for the annotation are intonation and the manner of the answer.

We observed informally a decline in the childrens' engagement in OAT later in the interactions. This was particularly so for OAT about diary or diabetes, while topics like free time or nutrition (favorite foods, weirdest food) were usually answered more willingly. However, there is no statistically confirmed general trend that engagement drops. It is clearly true for some children, while others maintain more or less the same level. Due to large individual variety we cannot conclude what system behavior triggers engagement.

It may be tempting to use the number of turns or subdialogues as a measure of the child's engagement in OAT. However, this is not the case, because sometimes the robot asks more times to get a satisfying answer. All annotators found that the *most positive* interaction is the one in which the child speaks with the robot as if it were a *real*

[3]The robot normally introduces itself by name at the beginning of the interaction. In this case, the session was continued after a technical problem.

play mate and not just a robot. This child has as many turns as others who seemed to become annoyed at the end of the interaction. Full responses do not appear to correlate with engagement either, but rather with the topics and the question type.

6 DISCUSSION AND CONCLUSIONS

In this paper we present the analysis of OAT subdialogues collected in a WOZ experiment with a conversational human-robot interaction system designed to provide, through different activities, useful contents to children with type I diabetes with the aim to help them in managing their condition. We investigate the distribution and character of OAT subdialogues and the responses of the children to the system-triggered OAT stimulation and observe the following: (1) children generally respond to the robot's prompt; (2) majority of full and elaborated responses occured on the diabetes topic; (3) the majority of responses on other topics are brief, which is likely at least partially due to their formulation of the prompts as closed questions; (4) a valuable number of children initiated OAT addressing the robot, thus making obvious the requirement to formulate a consistent background story for the robot character as part of the OAT design; (5) most of the children conducted the dialogue with the robot in a very natural way (e.g., they were engaged and interested, reciprocated OAT); (6) the engagement of some children decreased with the progress of the interaction.

Apparent lack of engagement is hard to interpret, because it is impossible to distinguish between disinterest in OAT topics as such (e.g., due to personality traits), or a reluctance to disclose personal information, or simple interest in and concentration on the main activity. Regarding the observed decreased interest in OAT with the progress of the interaction, we have also to take into account the fact that the system response was often extremely delayed or fragmentary and the synthesized speech output was hard to understand for long/complex utterances. Our aim in the near future is to automate OAT, so as to avoid long waiting times due to the wizard's typing.

On the other hand, the results obtained in this study are admittedly idealized due to the fact that there was no noise due to speech recognition and/or interpretation errors. In future work we need to study strategies for coping with these, as well as possible alternative OAT strategies and the adaptation of the system behavior to that of the child, in various respects.

Besides engagement, OAT has also a tangible effect on the relationship building process: observers (the psychologist and experimenters) note that when the robot asks more personal questions focused on the child, the child becomes curious and surprised. In a number of cases this leads to reciprocal questions, so as to start a "real" conversation with a friend who cares about their interests, habits, feelings, thus corroborating the evidence presented in (Kruijff-Korbayová et al., 2014). The fact that the children ask similar questions suggests that they imagine that the robot can have similar habits and preferences (even also about food or having diabetes, which is irrational if we consider it disengaged from the coversation). This perceived "humanization" of the robot fosters the concept of OAT as a means for observation and eliciting self-disclosure by the care givers, exerting a different approach in a sort of engaging and warming interaction (from an emotional point of view) and triggering, for example, a positive interplay between the establishment of a relationship and the adherence to specific medical guidelines.

In (Kruijff-Korbayová et al., 2014) we report findings concerning the overall effect of OAT: We have qualitative evidence that the presence of OAT during the individual interactions is linked both to a positive effect on the children's perception of the robot, inducing them to see it as a friend and then feeling free and at ease during the playing session, and to a better adherence towards specific medical guidelines like filling in a nutritional diary. Moreover, we found a statistically significant correlation between the presence of OAT in the interaction and the propensity of children to plan and participate in further interaction(s) with the system, in comparison to the non-OAT condition. An interesting topic for future work is to investigate whether any of the OAT characteristics studied in the current paper correlate with the overall effect of OAT.

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