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Using a robot to personalise health education for children with diabetes type 1: A pilot study

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ABSTRACT

Objective: Assess the effects of personalised robot behaviours on the enjoyment and motivation of children (8–12) with diabetes, and on their acquisition of health knowledge, in educational play.
Methods: Children ($N = 5$) played diabetes quizzes against a personal or neutral robot on three occasions: once at the clinic, twice at home. The personal robot asked them about their names, sports and favourite colours, referred to these data during the interaction, and engaged in small talk. Fun, motivation and diabetes knowledge was measured. Child–robot interaction was observed.
Results: Children said the robot and quiz were fun, but this appreciation declined over time. With the personal robot, the children looked more at the robot and spoke more. The children mimicked the robot. Finally, an increase in knowledge about diabetes was observed.
Conclusion: The study provides strong indication for how a personal robot can help children to improve health literacy in an enjoyable way. Children mimic the robot. When the robot is personal, they follow suit. Our results are positive and establish a good foundation for further development and testing in a larger study.
Practice implications: Using a robot in health care could contribute to self-management in children and help them to cope with their illness.

1. Introduction

Children aged 8–12 with diabetes type I are encouraged to get involved in their diabetes management in order to minimise the impact of their illness on their short- and long-term health [1]. Diabetes self-management is positively associated with metabolic control and health-related quality of life [2–9]. It consists of monitoring carbohydrate intake, physical activity and blood glucose, recognising symptoms of hypo- and hyperglycaemia, and injecting insulin to regulate blood glucose levels accordingly. In children under 12, parents play a prominent role in diabetes self-management and children do not therefore experience significant problems. However, as children move towards autonomy during puberty, it is important that they become more skilled at self-management [10].

Knowledge plays an important role in diabetes self-management. Greater knowledge can contribute to more effective management, better adherence, and improved HbA_{1c} [11,12]. In turn, knowledge can be enhanced through education about self-management topics such as blood glucose monitoring, insulin replacement, diet, exercise, and problem-solving strategies [11].

1.1. ALIZ-E: personalised and long-term child–robot interaction

The European 7th framework (FP7) project ALIZ-E is looking at how personal robots can help children to cope with their chronic disease and improve their self-management through adaptive and long-term educational interaction (www.aliz-e.org). A recent study by an international research consultancy, Latitude, showed that children respond well to learning environments that incorporate robots [13]. A recent study has further shown that children, who are engaged in physical and verbal social behaviours with a humanoid robot, believe that the robot has mental states (i.e., is intelligent and has feelings) and is a social being (e.g., could be a friend, offer comfort, and be trusted with secrets) [14]. This suggests that children in general are likely to feel related or socially connected to humanoid robots. Other studies have shown that interacting with a personal robot can help improve learning. For example, Janssen et al. studied the effect of the personalisation of a

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robot on children aged 9–10. They performed maths assignments in 3 sessions over a period of 3 weeks with either a robot that accompanied them to a group-based ceiling level or with a robot that accompanied them until they reached their personal ceiling level [15]. The personal robot showed interest in the child (e.g., remembered his/her name) and showed social behaviour at appropriate moments (e.g., was motivating when necessary). Both robots proved to be motivating and fun to use, but the personal robot generated more engagement. Other studies have shown the benefits of gaming for diabetes education. In their review, DeShazo et al. studied video game interventions for diabetes type 1, including quizzing, skill training and decision-making on PCs, smart phones and consoles. The authors found positive outcomes in knowledge, disease management adherence and clinical outcome [16].

1.2. Personal robot for developing diabetes self-management knowledge

On the basis of these studies, we developed a personal robot which contributes to children's diabetes knowledge by playing a game with the children. The robot plays a quiz with the child, with questions covering topics of interest to children (e.g., TV, maths, geography) and diabetes type I. Moreover, the robot is personal. In other words, it develops a user model and adapts the child–robot interaction accordingly.

The robot is a Nao, an autonomous, programmable humanoid robot developed by Aldebaran Robotics. As illustrated in Fig. 1, the child–robot interaction is based on an integrated system comprising different modules. These modules are: a dialogue model, user model and reasoning engine, a memory, and sensors for automatic speech and gesture recognition. In addition, the architecture includes different child–robot activities, such as playing a quiz, a dance or an imitation game.

The child–robot interaction is partly Wizard-of-Oz (WoOz). This implies that the robot behaves autonomously, but the researcher conducting the test partly simulates the dialogue model and the sensors. This includes telling the robot which phase of the interaction to start (in other words, introduction, explanation of the quiz, quiz, and closing) and communicates what the child is saying to the robot (for example, the child's name, questions asked and answers given). The two modules - the dialogue model and the sensors for automatic speech recognition – are currently being developed as part of ALIZ-e by the other project partners. Moreover, with the knowledge developed in our main study, we will contribute to the further development of the user model (in other words, what static and dynamic data does the robot need from the child in order to adapt its verbal and non-verbal behaviours and to contribute to long-term interaction).

1.3. Research question

This paper describes our first field study in a medical setting. Children aged 8–12 with diabetes interacted with a personal robot at different times and locations. The aim was to establish an empirical basis for the "learning by playing with a robot" approach and the effects of personalisation as a substantial step in the iterative development of the ALIZ-E robot. The issue we wished to address was: "How can a personal robot contribute to children's perceived enjoyment, motivation, and knowledge of diabetes?".

2. Methods

2.1. Participants

The participants were children (girls and boys) aged 8–12 with a diagnosis of diabetes type I dating back at least 6 months. Children with multi-morbidities were excluded. Participants were

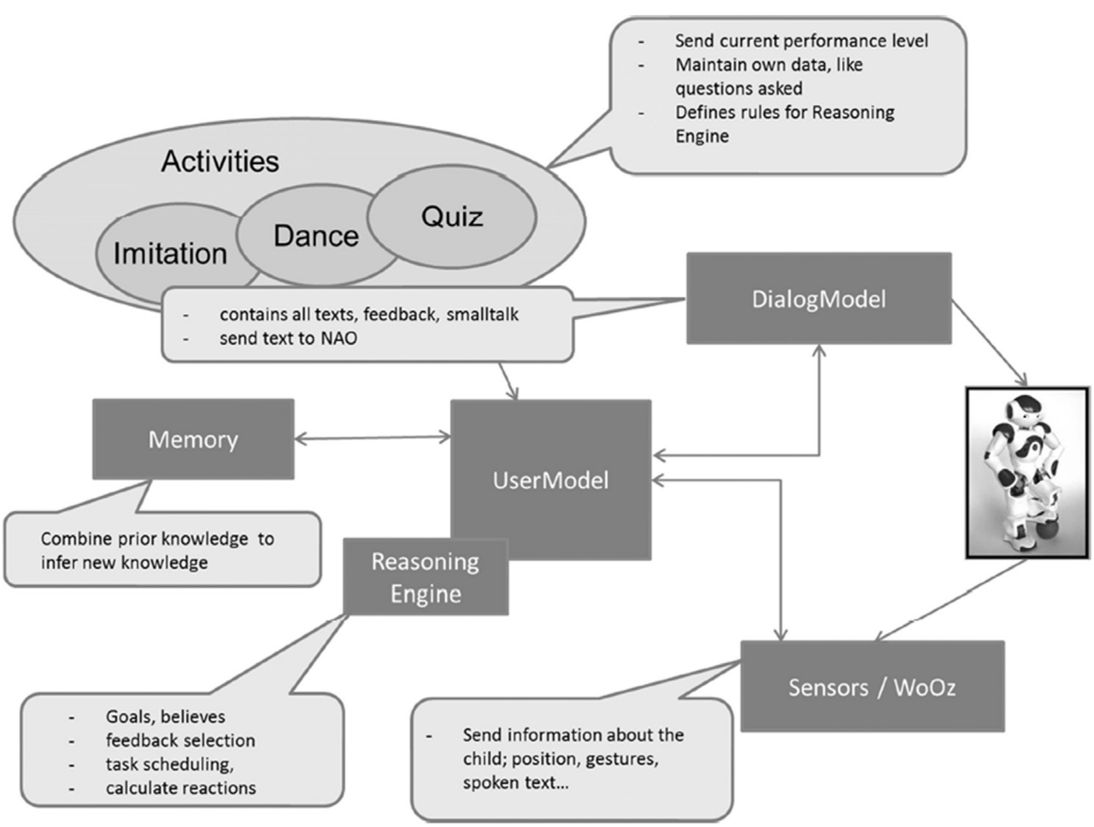

Fig. 1. Architecture for robot interacting with child during different activities, long term.

recruited through the paediatrics department, the Wilhelmina Kinderziekenhuis (WKZ), of the University Medical Center Utrecht (UMCU). The study protocol was approved by the UMCU ethics committee. Parents and children received a letter with information about the study (goal, results, contribution to ALIZ-e project, data processing and rights) and an invitation to participate in the pilot study. Parents gave informed written consent to participation in the study and children provided verbal assent and an initialled consent form. It should be noted that the disease involves ongoing unpleasant experiences, during hospital visits for example, and that the burden for children associated with participation should be minimal (they are already involved in multiple tests and examinations). A total of 12 children and their parents were invited to participate in this study.

2.2. Study design

As illustrated in Fig. 2, the study was conducted in three sessions at intervals of two to three weeks. The first session took place at the clinic as part of the regular check-up at which the child also met the diabetes paediatrician, nurse, dietician and psychologist. After giving informed consent, the accompanying parent(s) and children filled in a pre-test questionnaire. The robot then introduced itself, asked for the child's name, age, favourite colour

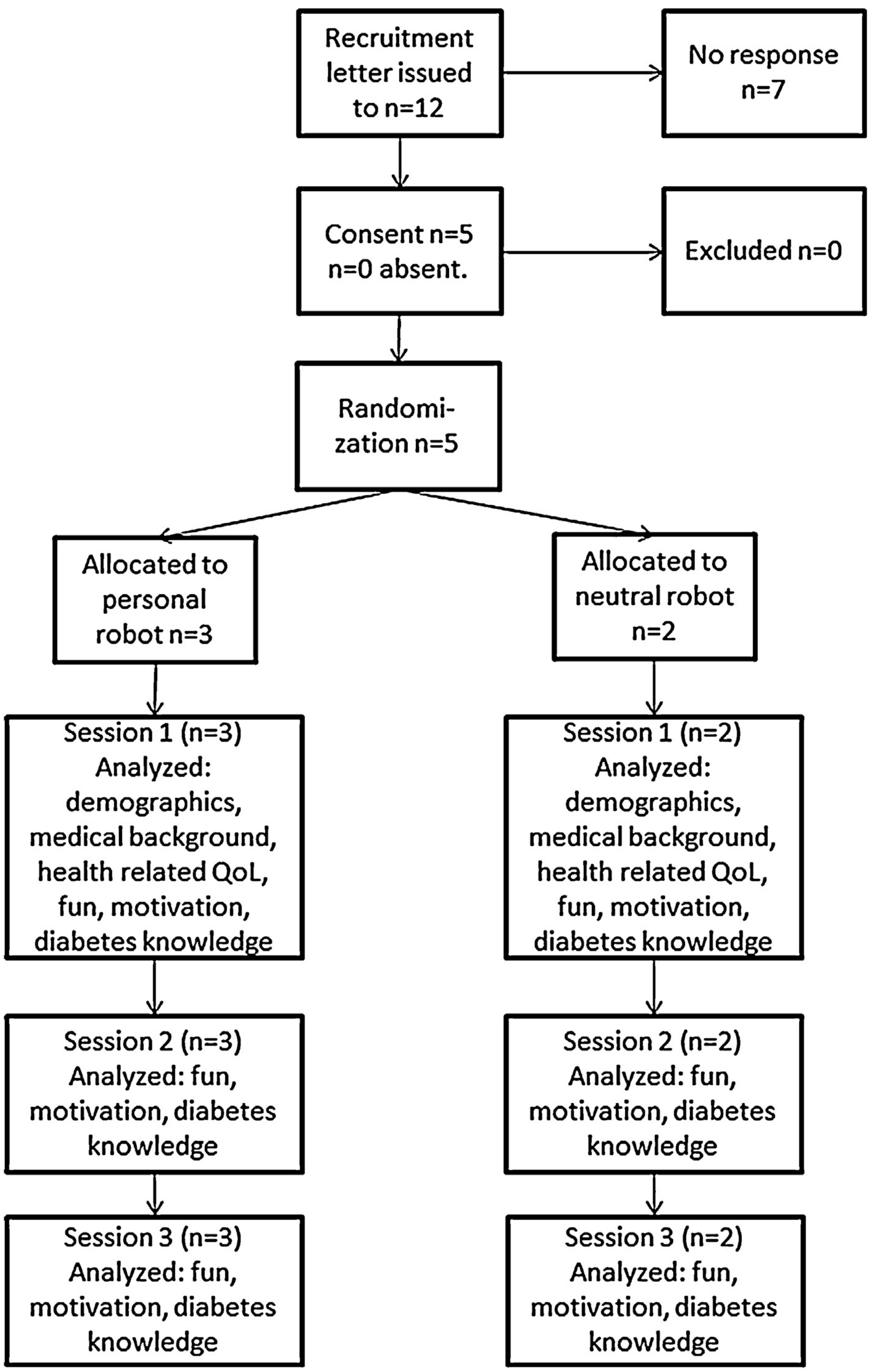

Fig. 2. Flow diagram for the pilot study.

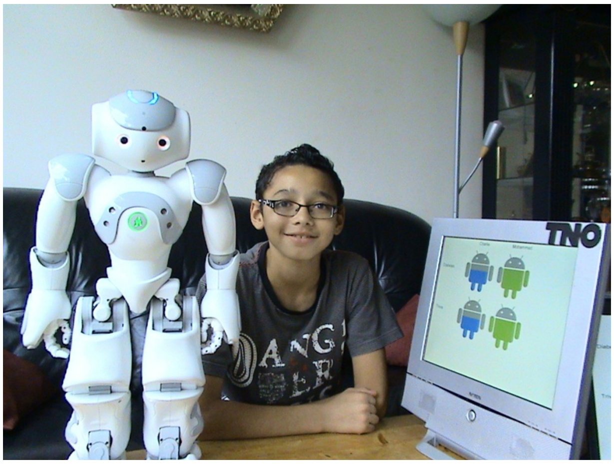

Fig. 3. Child diabetes patient with the robot and scoring screen.

and activity, and explained the Trivial Pursuit® style quiz. The child and robot took turns asking multiple-choice quiz questions about diabetes (for example, "What is a healthy sugar level for children?" and "How do you recognise a hypo?") and topics of interests for children (such as "What do you find at the centre of the earth?" and "If one arm of an octopus has 50 million cells, how many cells do an octopus' arms have in total?"). There were a total of 24 questions in the game, 12 of which were about diabetes. As shown in Fig. 3, the child and robot both had a monitor displaying the quiz question and the multiple-choice answers. The child and robot played three quiz rounds, each consisting of four questions. After three rounds, the robot offered to play a fourth round or to end the game. At each session therefore, the child and robot could answer a total of 20 questions, 10 of which were about diabetes. Finally, the child completed a questionnaire. In the second and third sessions, which took place at the children's homes, the procedure for the child was repeated, except for the introduction. The first session took approximately 45 min and the second and third session approximately 30 min.

2.3. Intervention

The study was organised using a between-subject design: children completed a quiz and were allocated randomly to a personal (intervention group) or a neutral robot (control group). Playing a game like the diabetes quiz allows the child to enhance their knowledge about health [17]. The personalisation of the robot while playing a quiz was based on the self-determination theory (SDT). SDT is based on the idea that players of all types seek to satisfy particular psychological needs in the context of play [18]. In their efforts to understanding better what makes games "fun", Ryan et al. have used this framework to explain the motivational "pull" of video games. SDT suggests that intrinsic motivation is the core type of motivation underlying play in general [19]. Children typically play because "it's fun". Three psychological needs that are of particular interest in the context of play are *autonomy*, *competence* and *relatedness*. The fulfilment of each of these psychological needs is thought to support intrinsic motivation and psychological wellness, and was in fact found to be an independent predictor of enjoyment and future game play [20]. In the SDT framework, *autonomy* refers to the sense of volition or willingness when doing a task [21]. Autonomy within game play can be enhanced by game designs that provide flexibility with respect to tasks (in other words, the child can choose to continue playing the quiz) and deliver feedback rather orders. The use of a personal robot is likely to enhance the sense of autonomy in children since the robot encourages the children to suggest activities themselves for managing their diabetes (for example: "You're playing outside with friends and need to urinate frequently. What is happening?"), and is programmed to give children feedback about their behaviour (for example: "Yes, that is the correct answer"). A second psychological need that was found to affect intrinsic motivation in game play is *competence*; the need for a challenge and the feeling of *effectance* [22]. In games, a sense of competence can be enhanced by providing the player with opportunities to acquire new skills and abilities, by offering a certain degree of challenge, and by giving the player positive feedback. In the present study, playing a quiz about diabetes is likely to enhance the child's feelings of competence, not only because of the challenging nature of the quiz, but also as a result of the comments and positive feedback from the personal robot. For example, at the end of each quiz round, the robot makes small talk, asking the children how they feel about the game (discussing topics such as fun level, level of difficulty, and expectations about winning or losing). The personal robot also comments on the child's response and therefore encourages competition (for example: "You're winning, but I will do my best to catch up!"). The third psychological need that is thought to enhance motivation and wellness is *relatedness*, which is experienced when a person feels connected with others [23]. More specifically, SDT hypothesises that environments that support perceptions of social relatedness improve motivation, positively influencing learning behaviour [20]. In the present study, the personal robot is expected to enhance the sense of relatedness and social connection by using the child's name during the interaction, adjusting the colour of its eyes to the child's favourite colour and referring to the child's preferred activity in the diabetes quiz questions (for example: "What do you need to do for your diabetes before you play football?"). In addition, the results of a previous study focusing on childhood diabetes revealed that children with diabetes enjoy attending diabetes camps and having friends with diabetes due to a common understanding of their condition [10]. As the personal robot in the present study displays an understanding of their condition, feelings of relatedness were expected to be enhanced, furthering motivation and enjoyment in engaging with the robot.

2.4. Measures

At the outset of the study, we asked the parents about their children's demographic details, medical background and health-related quality of life. The children were questioned during the study about the fun they had with the robot and the quiz, their motivation with respect to playing the quiz, and their diabetes knowledge. Health-related quality of life measurement was based on the MIND Youth Questionnaire (MY-Q), which covers the following domains: mental, physical and social well-being, and diabetes management (that is to say: feeling in control) [24]. Fun with the robot and the quiz was measured after each session on a five-point Likert scale using emoticons representing (1) no fun at all, (2) not much fun, (3) neutral, (4) fun, and (5) a lot of fun. The children could also say in their own words what they liked and disliked about playing the quiz with the robot. The measurement of motivation was based on the child's decision to play a fourth round or not. Diabetes knowledge was measured before and after playing the quiz with a diabetes knowledge questionnaire. The knowledge questionnaire was developed with the health-care professionals from the WKZ children's hospital. The questionnaire and quiz questions stemmed from materials used at the clinic (in other words, folders, booklets and websites) and were reviewed by the diabetes nurse. This ensured that the education provided during the study was consistent with the education provided during care as usual. In each questionnaire, the questions and multiple-choice answers were randomised. Finally, child interaction with the neutral and the personal robot was captured on video and audio. These recordings were examined, with the focus being on facial expressions (smiling and frowning, for example), gaze (that is to say, looking at the robot, the monitor or elsewhere), body posture and things said to the robot.

2.5. Statistical analysis

Data were checked for normal distribution using graphical summary of data, assessment of skewness, descriptive statistics, and tests of normality. For initial between-group comparisons of data, *t*-tests were carried out on the change in variables over time. This first field study will produce the data necessary to estimate the power for a subsequent full-scale Randomised Control Trial. In the full RCT, our aim will be to measure the interaction effect of the response variable group on participants' perceived fun, motivation and knowledge.

3. Results

3.1. Participants

A total of 12 children and their parents (all eligible) were invited to participate. Of these, five children (three boys and two girls) consented to participate. The minimum age was 9 and the maximum age was 12 ($M = 10.20$, SD = 1.30). Children were in the third ($n = 1$), fourth ($n = 1$), fifth ($n = 1$) and sixth grades ($n = 2$) of elementary school. Their active hobbies were dancing ($n = 1$), field hockey ($n = 1$), tennis ($n = 1$) and football ($n = 2$).

As shown in Table 1, the children had had diabetes for an average of 68 months (SD = 16.58) and they all were treated with an insulin pen and syringe. The minimum HbA_{1c} was 7.1 and the maximum 8.2 ($M = 7.76$, SD = 0.43). On a scale from 1 (low) to 5 (high), parents stated that their children's control of their diabetes on average was 3.40 (SD = 1.14), mental well-being 3.60 (SD = 0.89), physical well-being 3.60 (SD = 0.89), and social well-being was 3.80 (SD = 0.45). Moreover, on a scale from 1 (little) to 5 (a lot), parental support on average was 5.00 (SD = 0.00) and the child level of responsibility was 4.00 (SD = 0.71). The demographic data for the two groups did not differ by more than 10%, except for the children's score for control of diabetes. The personal robot group scored 4.00 out of 5 (SD = 1.00) on average and the neutral robot group scored 2.50 out of 5 (SD = 0.71) on average.

3.2. Fun

As Fig. 4 shows, the children rated the perceived fun with the robot for the three sessions on a scale of 1 (not at all) to 5 (a lot). The results were, respectively, 4.80 (SD = 0.48), 4.80 (SD = 0.48) and 4.00 (SD = 0.71). There was a significant decline: $t(4) = 4.00$, $p = 0.016$ over the course of the three sessions. In addition, as can be seen in Fig. 5, when rating the quiz on a scale of 1 (not at all) to 5 (a lot), the children's scores were 4.60 (SD = 0.55), 4.60 (SD = 0.55) and 3.80 (SD = 0.45) respectively. Once again, there was a significant decline: $t(4) = 4.00$, $p = 0.016$.

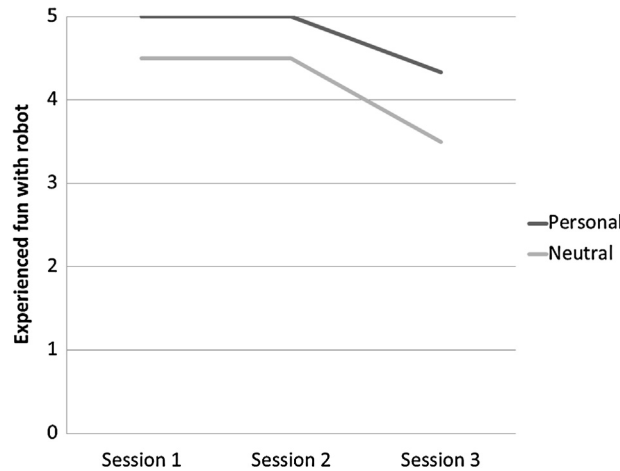

Fig. 4. Children's perceived fun with the personal and neutral robot over three sessions ($N = 5$).

3.3. Number of quiz rounds played

As Table 2 shows, four children played four rounds of the quiz with the robot in sessions one and two. Only two children played a fourth round in session three. These children were both playing with the personal robot. The decline in number of rounds played was not significant.

3.4. Knowledge

At baseline, children answered 13 (SD = 2.35) of the 20 questions correctly on average. At the end of sessions one, two and three respectively, they answered 16.20 (SD = 0.89), 17.60 (SD = 1.64), 18.20 (SD = 1.30) questions correctly on average. There was a significant increase, $t(4) = 3.47$, $p = 0.025$ (Fig. 6), between the first and last questionnaire in the number of questions answered correctly.

3.5. Children's comments

Children said why they like playing the quiz with the robot and what they liked most and least about the robot itself. The children

Table 1
Baseline characteristics of study participants, total and per group ($N = 5$).

Gender	Total				Personal robot				Neutral robot			
	3 boys; 2 girls				2 boys; 1 girl				1 boy; 1 girl			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Age	9	12	10.20	1.30	9	11	10.00	1.00	9	12	10.50	2.12
Diabetes since (months)	46	90	67.60	16.58	46	90	69.33	22.12	58	72	65.00	9.90
HbA1c	7.1	8.2	7.760	0.43	7.1	8.0	7.67	0.49	7.6	8.2	7.90	0.42
Control of diabetes	2	5	3.40	1.14	3	5	4.00	1.00	2	3	2.50	0.71
Mental wellbeing	3	5	3.60	0.89	3	5	4.00	1.00	3	3	3	0.00
Physical wellbeing	3	5	3.60	0.89	3	5	4.00	1.00	3	3	3	0.00
Social wellbeing	4	5	4.80	0.45	4	5	4.67	0.58	5	5	5.00	0.00
Parental support	5	5	5.00	0.00	5	5	5.00	0.00	5	5	5.00	0.00
Level of responsibility child	3	5	4.00	0.71	3	5	4.00	1.00	4	4	4.00	0.00
HbA1c	7.1	8.2	7.760	0.43	7.1	8.0	7.77	0.49	7.6	8.2	7.90	0.42

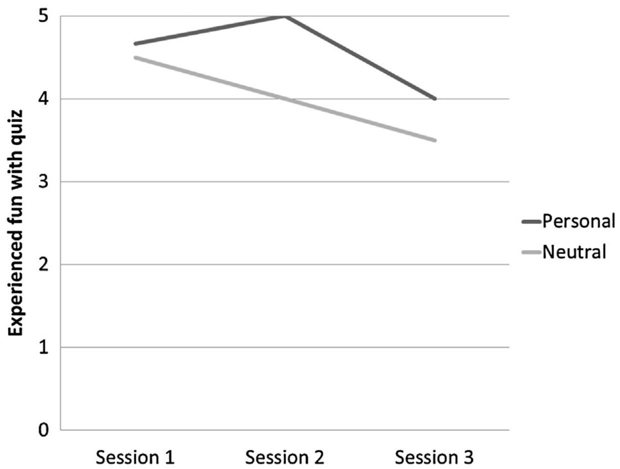

Fig. 5. Children's perceived fun with the quiz over three sessions, played with personal and neutral robot ($N = 5$).

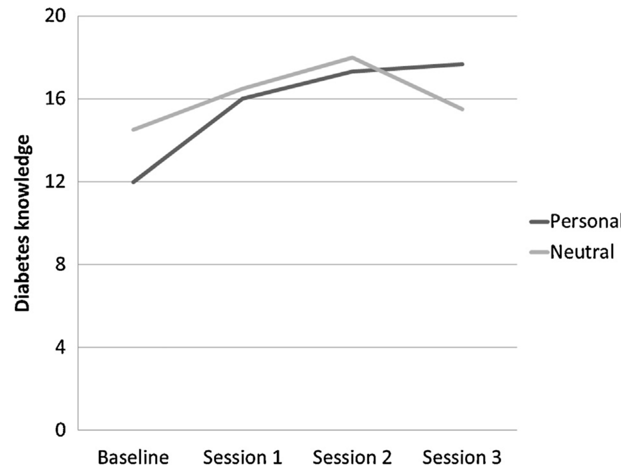

Fig. 6. Children's diabetes knowledge with personal and neutral robot, at baseline and over three sessions ($N = 5$).

said that they liked playing the quiz with the robot because "he knows a lot", "he is funny", and they were curious how they would perform next time. They disliked the repetition in the quiz questions. What they liked most about the robot was that he changed the colour of his eyes to the child's favourite colour, "he can talk and move", and "he is very friendly". One child simply liked everything about the robot. What they liked least was that "he is sometimes slow to answer".

3.6. Children's interaction with personal and neutral robot

Observations of the video recordings displayed a number of similarities and differences during the interaction (in facial expression, gaze, body posture, and verbal utterances) in the intervention and control groups during the three sessions. Similarities in interaction with the personal and neutral robot were as follows. All children looked pensively at the monitor and sometimes frowned when thinking about the answers to the questions asked. The children mainly looked at the robot and the monitor. Later on in the session, the children started to look elsewhere (for example, scanning the room, staring at their own hands, looking under the table or out of the window). Children started the session sitting close to the monitor and robot. Over the course of the session they adopted a more reclining position. They continuously fiddled with their hands, clothing and/or jewellery. The children responded enthusiastically when they won the quiz (smiling, cheering or saying "Yippee!", for example).

Differences were also observed between the groups. The children interacting with the personal robot looked longer and more often at the robot. They watched the robot at length or frequently looked at the monitor and robot alternately. Children interacting with the neutral robot only looked at the robot when it asked them a quiz question. Children working with the personal robot were elaborate in their utterances, used the robot's name and expressed empathy and were encouraging (for example: "Well played, Charlie", "Sorry, Charlie. That is not the right answer", and "That is almost the right answer. You can try again". The 11-year-old boy in the personal robot group complimented the robot on its performance (robot: "Congratulations, M. That is the correct question." M.: "Thank you Charlie. You played well, too"). Children interacting with the neutral robot used short, direct statements when talking to the robot ("That's right" and "The right answer is B", for example). Children interacting with the personal robot were cheerful when answering a question correctly. The children interacting with the neutral robot did not respond emotionally to answering a question correctly or not.

One notable change was observed during the sessions. From session 2 onwards, the children mimicked the robot's verbal utterances, which was unusual due to the text-to-speech software used. Children mimicked how the robot spoke, articulating clearly and pausing between words. They also mimicked the robot's speech patterns and vocabulary. For example: "Unfortunately, Charlie, that is not the correct answer. The correct answer is A." and "On what side of the road do you drive in Thailand, question mark" (the robot's speech synthesiser currently indicates a question by saying the words "question mark" at the end of interrogative sentences).

The two older children (who were 11 and 12 years old) played along with the robot when it made an error or was unrealistic. For example, the 12-year-old girl laughed out loud when the robot continued speaking when the child had already answered the question and then responded with slight tone of sarcasm in her voice. In another case, the robot said, as part of the small talk, that it would try to catch up although the boy was a long way ahead in points. The 11-year-old boy said that he believed the robot, but his voice expressed doubt and he was smiling.

Table 2
Number of children who played four quiz rounds with the personal or neutral robot ($N = 5$).

Condition	Session 1	Session 2	Session 3
Played four rounds with personal robot ($N = 3$)	2	2	2
Played four rounds with neutral robot ($N = 2$)	2	2	0
Total	4	4	2

4. Discussion and conclusion

4.1. Discussion

The present study provides strong indication for how playing a quiz with a personal robot can enhance children's perceived enjoyment of learning and help them learn about diabetes.

Our pilot study includes only 5 participating children and covers only 3–4 sessions. The results are nonetheless encouraging. They provide strong indications that playing a quiz with a personal robot can enhance children's perceived enjoyment of learning and help them learn about their illness, in this case, diabetes.

Playing with the robot enhanced diabetes knowledge and was rated as fun. In the third session, the fun level was lower. Nevertheless, it remained high and although the novelty had worn off somewhat, the children still continued to engage and learn. Moreover, children interacting with the personal robot looked more at the robot and were more elaborate in verbal utterances than children interacting with the neutral robot. In addition, the children started to mimic the robot verbally over time.

The results are promising and a number of improvements were identified which will be incorporated in the planned field study. With respect to the study design, we found that evaluating the robot at home costs a lot of time and we found that the children were more easily distracted. We will therefore be conducting the main study with children solely at the clinic. In addition, we will be studying the possibility of remote interaction between the children and the robot, for example through online video conferencing, without losing the benefits of the robot (the enhancement of fun levels, motivation and knowledge).

The children thought the robot and quiz were fun and motivating but they disliked the repetition in the quiz questions and the slow responses of the robot. We will therefore be developing the database of quiz questions further and making technical changes to speed up the robot responses. In addition, during the study, we found that the robot was usually in the lead. Since we want to achieve relatedness, we would prefer the robot and child to interact at the same level. As a result, we will be giving the children more opportunities to contribute to the interaction, for example, by extending the introduction and encouraging the children to ask the robot questions about things like its background and preferences.

We observed that, although children express high levels of fun in the surveys and were motivated to continue playing with the robot, there was a distinct difference in their engagement levels over time. At the beginning of a session, the children would sit on the edge of the chair and focus on the robot. Later on during the session, the children would adopt a more reclining position and be less focused on the robot. As a result, we will continue to observe the level of engagement on the basis of qualitative data relating to the children's facial expressions, gaze, body posture and things said to the robot.

In addition, research has shown that ''flow'' in the use of information technologies is positively related to (1) high levels of skill and control; (2) high levels of challenge, fun and arousal; and (3) motivation and focused attention and engagement [25]. Flow is ''the holistic experience that people feel when they act with total involvement'' [26]. When they are ''in the flow'', people become absorbed in their activity: their awareness is narrowed to the activity itself; they lose self-consciousness, and feel in control of their environment. We observed this in some children (in other words, they were totally absorbed in the interaction with the robot). We are therefore interested in how flow is elicited during child–robot interaction and how it relates to a child's perceived fun, motivation and knowledge.

The children paid close attention to the robot and the monitor but children interacting with the personal robot looked more at the robot and were more elaborate in verbal utterances than children interacting with the neutral robot. The children also started to verbally mimic the robot over time. This nuances the usual thinking about the need to personalise robots by mimicking human behaviours. Children would seem to tend to mimic robots and, when the robot is more elaborate verbally and expresses emotions during the interaction, it would appear that the children follow suit. Most studies focus on how robots mimic humans, but we argue that it would be interesting to study how humans mimic robots as well.

Our aim is to study the effects of a personal robot – a robot that attunes interaction to the child on the basis of a dynamic user model (including factors such as name, preferences, current emotions and previous interactions) – on health knowledge that can contribute to self-management. Considering our current findings and the literature on the relationship between self-determination, fun and motivation, we expect children to be more likely to enjoy interacting with the personal robot more than interacting with a neutral robot and to continue to interact over a longer period of time [18,19]. Moreover, playing an educational game such as a diabetes quiz may contribute to an understanding of how to manage an illness and could, in turn, help children to cope with their illness [4,10].

These anticipated effects are not only relevant for children with diabetes or with other illnesses requiring self-management such as asthma. Healthy children could also benefit from a personal robot. This approach could, for example, help children to cope with different issues that negatively affect their well-being such as bullying. Bullying in schoolchildren is a major problem and various interventions have been developed to deal with bullying at school such as training in different bullying situations [27]. The personal robot could facilitate such interventions by rehearsing with the child how to cope with bullying peers in a personal, enjoyable and motivating way.

Based on the findings of the empirical studies with the robot, an agent-based module is being developed and tested for reasoning about the implicit (sensor-generated) and explicit (user-generated) data and generating effective adaptive robot behaviours on the fly [28]. These data feed as ''percepts'' into an up-to-date user model containing beliefs of both user's stable personal information (e.g., traits and preferences) and user's momentary condition, intentions and performances (e.g., knowledge, motivation and mood). By reasoning about these beliefs, undesirable user states and performances can be presumed that, subsequently, trigger dedicated mitigation strategies (e.g., a sudden drop in performance can be an indication of a reduction in motivation to be mitigated by (1) encouragement when the goal performance is almost reached or (2) proposing an in-between activity when there are also other goals). The selection and instantiation of the mitigation is based on relevant theories and methods, for example, on self-determination [18], competences [22], and behaviour change techniques (such as ''Encourage use of self-instruction and self-encouragement (aloud or silently) to support action'') [29]. This way, user's personal ability and (intrinsic) motivation to interact and to perform the activities, such as a quiz, are supported. We use the believe-desire-intention (BDI) agent-platform GOAL (Goal-Oriented Agent Language) to implement this reasoning mechanism [30].

4.2. Conclusion

This study shows how a personal robot can help children to improve their health knowledge in a relatively enjoyable way. The results showed an overall increase in diabetes knowledge. Children rated the robot and quiz as fun. This fun level fell over time but remained relatively high. The children verbally mimicked the robot and also did so when it was more personal in the interaction. Overall, the evaluation results are positive and represent a good basis for further development and testing in a larger field study.

The children complied with the study procedure and they were positive about the intervention. The study materials were suitable for measuring fun, motivation and diabetes knowledge. Potential improvements in robot behaviours and the evaluation method were identified.

4.3. Practice implications

Introducing a robot approach to health care education could help children to cope with their illness. In addition, when the robot succeeds in developing personalisation with the child, fun, motivation and knowledge may be enhanced in the long term. This is required to prevent users, such as children, losing interest in the short term at the cost of the intervention's efficacy.

Conflict of interest

The authors report no conflict of interest in this work.

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