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# Design and evaluation of a personal robot playing a self-management education game with children with diabetes type 1



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## ABSTRACT

*Objective:* To assess the effects of a personal robot, providing diabetes self-management education in a clinical setting on the pleasure, engagement and motivation to play a diabetes quiz of children (7-12) with type 1 diabetes mellitus (T1DM), and on their acquisition of knowledge about their illness.

*Methods:* Children with T1DM (N=27) participated in a randomized controlled trial (RCT) in which they played a diabetes mellitus self-management education (DMSE) game, namely a diabetes quiz, with a personal or neutral robot on three occasions at the clinic, or were allocated to a control group (care as usual). Personalised robot behaviour was based on the self-determination theory (SDT), focusing on the children's needs for competence, relatedness and autonomy. The SDT determinants pleasure, motivation and diabetes knowledge were measured. Child-robot interaction was observed, including level of engagement.

*Results*: Results showed an increase in diabetes knowledge in children allocated to the robot groups and not in those allocated to the control group (P=.001). After three sessions, children working with the personal robot scored higher for determinants of SDT than children with the neutral robot (P=.02). They also found the robot to be more pleasurable (P=.04), they answered more quiz questions correctly (P=.02), and were more motivated to play a fourth time (P=.03). The analysis of audio/video recordings showed that in regard to engagement, children with the personal robot were more attentive to the robot, more social, and more positive (P<.05).

*Conclusion:* The study showed how a personal robot that plays DMSE games and applies STD based strategies (i.e., provides constructive feedback, acknowledges feelings and moods, encourages competition and builds a rapport) can help to improve health literacy in children in an pleasurable, engaging and motivating way. Using a robot in health care could contribute to self-management in children with a chronic disease and help them to cope with their illness.

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## 1. Introduction

## 1.1. Self-management in childhood type 1 diabetes mellitus

The growing burden of chronic illness has led to an increasing focus on self-management in health care. This also applies to the increasing number of children with a chronic illness (WHO, 2010). For example, the incidence of childhood type 1 diabetes mellitus (T1DM) is rising rapidly, with a doubling time of less than 20 years (Patterson et al., 2009). T1DM is associated with serious short and long term complications, such as hypoglycaemia, nerve damage and micro- and macrovascular damage. These complications cause high morbidity and mortality, affect quality of life, and push up health-care costs. Complications can be reduced with optimal self-management (American Diabetes Association, 2003).

Children aged 7–12 with T1DM 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 (Dedding, 2012). Diabetes self-management is positively associated with metabolic control and health-related quality of life (Hood et al., 2009; Levine et al., 2001; Lynne et al., 2002; Hoey et al., 2001; Kalyva et al., 2011; Wagner et al., 2005). It consists of (1) monitoring carbohydrate intake, physical activity and

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blood glucose, (2) recognising and mitigating symptoms of hypo- and hyperglycaemia, and (3) administering insulin to regulate blood glucose levels accordingly. In pre-adolescent children, parents play a prominent role in diabetes self-management. As children move towards autonomy during puberty, it is important that they become more skilled at selfmanagement at an early age, albeit in line with their emotional, cognitive and physical skills (Blanson Henkemans et al., 2012; Scott, 2013).

## 1.2. Games for diabetes self-management education

Knowledge plays an important role in children's diabetes selfmanagement. Enhanced knowledge can contribute to more effective management, better adherence, and improved HbA1c (Couch et al., 2008; Roper et al., 2009). It is advised to provide self-management education for the treatment and prevention of hypoglycaemia, acute illnesses, and exercise-related blood glucose problems (American Diabetes Association, 2003; Qayyum et al., 2010).

Knowledge can be enhanced through Diabetes Self-Management Education (DSME) covering topics, such as blood glucose monitoring, insulin replacement, diet, exercise, and problem-solving strategies (Couch et al., 2008). Qayyum et al., (2010), for example, evaluated the effect of DSME on glycaemic control (HbA1c) in children suffering from T1DM. Those children were educated in two sessions, during which general information was provided about the disease, basic insulin therapy, planning for hypo- and hyperglycaemia, activity, travelling and basic nutritional management. A significant improvement was found in glycaemic control (in other words, HbA1c levels were found to be lower) in children who completed the DSME programme.

Various studies have shown the benefits of gaming for DSME. In their literature review, DeShazo et al., (2010) identified research on diabetes education video games, reviewed themes in diabetes video game design and evaluation, and evaluated their potential role in diabetes selfmanagement education. The authors found multiple video game interventions for T1DM on different platforms (PCs, smart phones and consoles), including quizzing, skill training and decision-making. Themes included self-monitoring, blood glucose, diet and exercise, and medical adherence. Overall, these games had a positive impact on knowledge and self-efficacy, disease management adherence and glycaemic control (hyperglycaemia and HbA1c). Notably, the authors also established that few of the reviewed video games were tailored to a diverse population with varied educational backgrounds and goals. This represents a missed opportunity, since personalisation, or "tailoring", can considerably contribute to the motivation to continue playing games and therefore to improve playing skills and knowledge (for example, Baranowski et al., 2008).

### 1.3. Personalised and long-term child-robot interaction

The European 7th framework (FP7) project ALIZ-E has been looking at how personal robots can help children to cope with their chronic disease and to improve self-management through adaptive and long-term educational interaction (www.aliz-e.org). The ALIZ-e project used the Nao, an autonomous, programmable humanoid robot from Aldebaran Robotics. Details on the interaction and activities between the child and Nao robot, the use of a "Wizard-of-Oz setup (i.e., the robot was partially operated by the experiment leader), system modules and architecture are further discussed in Blanson Henkemans et al. (2013).

Multiple other studies explored the benefits of personal robots for educating children. They show that personalisation has additional benefits for Child-Robot Interaction (CRI), regarding engagement, pleasure, fulfilling social needs and motivation. Also, personalisation proved to enhance the effects of CRI on developing math skills and increasing health awareness (e.g., Janssen et al., 2011; Van Der Drift et al., 2014, Tielman et al., 2014). These studies also showed a number of needs for further research on benefits of personal robots for educating children. First, these studies did not look at the effect of a personal, motivating robot for the development of knowledge required for self-management, in a clinical setting. Second, these studies looked at CRI on one occasion or a maximum of three occasions over a period of three weeks. It is unclear how the interaction is evaluated over a longer period of time. Finally, they lack a strong theory-based underpinning, such as the use of self-determination theory, for the intervention by the personalised robot.

Other research looks at the use of robots for individuals with Autism Spectrum Disorders (ASD). Illustratively, a literature review from Diehl et al., (2012) looks at different categories of robot research in this population. These categories are amongst others the use of robots to elicit behaviours (for example, promote prosocial behaviour), the use of robots to teach and practice a skill (for example, initiating a conversation), and the use of robots to provide feedback on performance (for example, positive reinforcement when performing social behaviour). Their results showed notably that most studies are exploratory and have methodological limitations. Based on these studies, it is difficult to draw firm conclusions about the clinical utility of robots in children with ASD.

Considering the benefits of a personal motivating robot discussed in the literature and need for further research on the effect of personalisation in CRI in a clinical setting over a prolonged period, with a strong theoretical underpinning, on developing diabetes selfmanagement knowledge, a pilot study was conducted. It tested a robot applying personalised behaviour, based on the self-determination theory, and playing a DSME quiz (Blanson Henkemans et al, 2013). Five children aged 8–12 participated in the study located at the Wilhelmina Children's Hospital (WKZ) in the Netherlands. The results of pre-post testing showed that diabetes knowledge was enhanced. In addition, the children said the robot and quiz were pleasurable, but this appreciation declined over time. The children looked more at the personal robot than the neutral robot and spoke to it more.

The outcomes of this pilot resulted in a study, described in the current paper. Children aged 7–14 with T1DM interacted with a personal or neutral robot at a diabetes clinic or were assigned to a control group (care as usual). As in the pilot, the aim was to establish an empirical basis for 1) a "learning by playing with a robot" approach over a prolonged period, and 2) the effects of personalisation on child-robot interaction in a clinical setting. Results could provide a considerable step in the further development of social robots, as studied in the ALIZ-E project.

## 2. Design of personal robot playing a diabetes game

## 2.1. Quiz to learn about diabetes

In this study, the child and robot played a diabetes quiz. They took turns in asking multiple-choice questions about diabetes (for example, "What do you do for your diabetes before performing sports" and "How do you recognise a hyper?") and topics of interests for children (such as "On what side of the road do they drive in Thailand?").

The child and the robot played three quiz sessions, one every six weeks. One session counted multiple quiz rounds, to a maximum of six. During one round, the child and robot both asked and answered two questions, of which one was about diabetes. After rounds three, four, five and six, the robot asked the child whether he or she wanted to play another round or to end the game. Thus, during each session, it was possible for the child and the robot to answer a total of twelve questions each, of which six were about diabetes. Within both categories of quiz questions (general and diabetes), the questions were fully randomized, although a quiz question was only posed once per session. As such, each question could be posed by the natural robot, the personal robot or the child. With this approach, we aimed at minimizing the impact of possible variance in the difficulty level of the questions on the children motivation and knowledge level.

The child and the robot shared a monitor (tablet PC). It displayed the quiz question, multiple-choice answers and the scores of both the robot and the child. The monitor was placed on a seesaw-like device, Download English Version:

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