A Social Robot-based Platform for Prevention of Childhood Obesity

Andreas Triantafyllidis
Information Technologies Institute
Centre for Research and Technology Hellas (CERTH)
Thessaloniki, Greece
atriand@iti.gr

Anastasios Alexiadis
Information Technologies Institute
Centre for Research and Technology Hellas (CERTH)
Thessaloniki, Greece
talex@iti.gr

Dimosthenis Elmas
Information Technologies Institute
Centre for Research and Technology Hellas (CERTH)
Thessaloniki, Greece
dimoselmas@iti.gr

Konstantinos Votis
Information Technologies Institute
Centre for Research and Technology Hellas (CERTH)
Thessaloniki, Greece
kvotis@iti.gr

Dimitrios Tzovaras
Information Technologies Institute
Centre for Research and Technology Hellas (CERTH)
Thessaloniki, Greece
Dimitrios.Tzovaras@iti.gr

***Abstract*—Childhood obesity is a major public health concern since it is associated with obesity during adulthood and the occurrence of diseases such as diabetes and cancer. In this paper we present a platform for childhood obesity prevention, which is based on interactive games played between a social robot and the child. The interactions between the robot and the child occur within four distinct stages: a) Familiarization with the robot, b) education and knowledge assessment (e.g., for a balanced diet), c) behavioural data collection & empowerment, and d) personalized goal-setting. The platform was evaluated in terms of usability with 10 participants achieving a System Usability Score (SUS) of 93.8. Overall, our results show the feasibility of the adopted approach and the potential of social robots in playing a major role for promoting healthy behaviours and preventing childhood obesity.**

Keywords—social robot, childhood obesity, robot games, artificial intelligence, child-robot interactions

I. Introduction

Childhood obesity is unarguably a serious public health challenge. Previous research has shown the association of childhood obesity with obesity in adult life, as well as the occurrence of chronic diseases such as diabetes, cardiovascular disease, and cancer [1]. According to the World Health Organization (WHO) statistics [2], it is estimated that 1 in 3 children at the age of 11 in Europe, is overweight or obese. In this context, it is important to design and develop interventions which could prevent the onset of childhood obesity, mainly through the adoption of healthy habits related to a balanced diet and regular physical activity.

Most digital health systems developed for childhood obesity prevention so far, make use of mobile or wearable devices (e.g., smartphones, smartwatches, pedometers, physical activity trackers, etc.) with limited interaction capabilities [3]. The adherence to the use of those devices by children has been questioned in the scientific literature [4]. Physical robots compared to virtual agents found in a screen of a computer device, provide engagement with the physical world and are more likely to elicit social behaviour from the learners and contribute to their intellectual growth [5]. In this context, the adoption of social robots, which enable natural interactions with the children through voice, gestures, and touch, can provide an interactive and entertaining way of delivering personalised education and guidance, that could increase the interest of children in acquiring healthy habits.

Social robots have been used for healthcare or educational purposes [6]–[8], however their use for childhood obesity prevention has been scarce [9]. In this work, we have designed, developed and evaluated a social robot-based platform which employs various robot-child games in order to provide a stimulating user experience, promote healthy

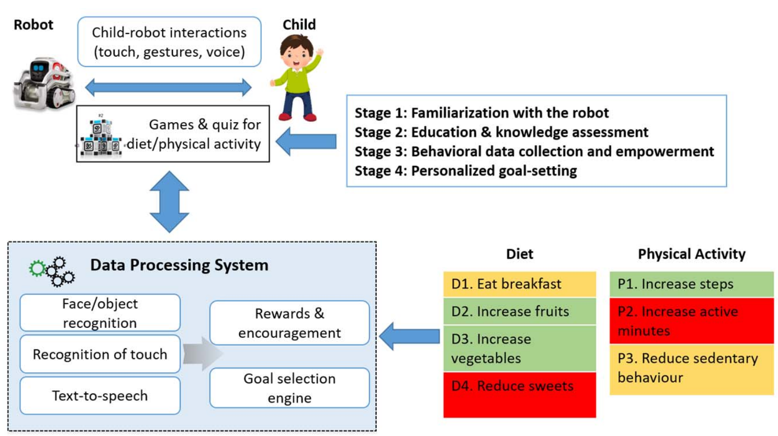

Fig. 1. Platform generic architecture

2471-7819/19/$31.00 ©2019 IEEE
DOI 10.1109/BIBE.2019.00171

behaviours, and ultimately guide children to the achievement of health goals based on their personal needs.

II. Methods

A. Platform Design

The generic architecture of our platform can be seen in Fig. 1. The platform enables child-robot interactions through a Data Processing System and a series of interactive child-robot games which can be played within the following 4 stages:

- **Stage 1: Familiarization with the robot –** In this initial stage children become familiar with the robot characteristics and behaviour. For example, the robot can recognise the face of the child (*face/object recognition*) and proceed with a sound, kinetic, or facial reaction (e.g., eye blinking).
- **Stage 2: Education & knowledge assessment –** In this stage a series of interactive health educational games are played between the robot and the child. The goal of the games is to provide education on healthy habits e.g., for diet and physical activity, through touch interactions (*recognition of touch*). The games between the child and the robot can be played with tangible objects which the robot can visually recognise and manipulate (e.g., touch, move and lift).
- **Stage 3: Behavioural data collection and empowerment –** In this stage the robot asks the child a series of questions about its health habits. The robot motivates children to change their health behaviour through speech (*text-to-speech*) if this is not optimal or maintain their behaviour if this is found to be optimal (*rewards & encouragement*). The questions are provided in the dimensions of diet and physical activity according to reliable instruments such as the Food Frequency Questionnaire (FFQ) [10] and the Physical Activity Questionnaire for Children (PAQ-C) [11]. The questionnaires are provided as an interactive quiz, in which the answers are given by the child through touching tangible objects such as cubes.
- **Stage 4: Personalized goal-setting –** In this stage, after processing the input behavioural data received within stage 3, the child is advised by the robot (through speech) to follow one specific goal (*goal selection engine*) for diet or physical activity for the following week. This is done according to a red-yellow-green flag (traffic light) decision scheme (according to responses given in the questionnaires of stage 3) in which a red flag denotes a behaviour which needs immediate change (i.e., prioritized behaviour), a yellow flag denotes a not optimal behaviour which requires change, and a green flag denoting an optimal health behaviour which needs maintenance (Fig. 1). In the case two or more behaviors have the same flag, random mission selection occurs at the current stage. However, a more sophisticated logic could be applied for goal selection, e.g., based on the analysis of historical data (for example, prioritization of behaviour which appeared to need immediate change most often in the past).

B. Technical Implementation

We used the Anki© Cozmo robot to implement the afore-mentioned games and quiz[1]. Cozmo is a small consumer robot with some interesting features:

a) It is palm-sized and easy to carry

b) It shows an engaging personality, e.g., showing feelings of happiness, sadness, anger, etc., through eye animations and movement with wheels, which is customisable via programming scripts

c) It is programmable via a Standard Development Kit (SDK) which has large community support

d) It incorporates a variety of sensors such as a camera for recognizing its environment (used e.g. for face recognition), a proximity sensor for obstacle detection, an accelerometer, and a cliff sensor to avoid falls

e) It can speak and it can display text/images on its display

f) It can interact (e.g., push or lift) with small tangible cubes which are part of the platform and empowered with accelerometers

g) It pairs with popular mobile phone platforms, e.g. Android, in order to control its behaviour

We used the Python programming language to program the games, which offers the advantages of rapid prototyping, efficient memory management, and cross-platform availability. Cozmo is controllable via a mobile application compatible with iOS and Android. The Cozmo SDK provided us with the ability to program asynchronous events required for example in the interaction with its cubes (e.g., when someone touches them).

We developed a series of games according to our platform design using the Cozmo Python-based SDK. For stage 1, the robot was able to detect a face (face/no face) through built-in computer vision and the application of the Viola–Jones object detection framework. For stage 2, a quiz with generic health education questions was developed (proof-of-concept), in which the answers among three available choices can be given upon touching one of the three cubes. Upon detection of the answer through human touch, the robot was programmed to respond with speech, eye animations and movement, depending on whether the answer is correct, providing reward and motivation (e.g., "well done", "congratulations", "next time you will know the correct answer", etc.). In another game, the cubes were accompanied with food images expecting the child to recognize the image with the healthiest food and bring the correct cube in front of the robot's camera. The robot reacts with a happy voice rewarding the child if the answer is correct, or otherwise it detects the correct cube and lifts it up. In this game we used a pre-defined mapping of correct answers to specified cubes which can be recognized by the robot. For stage 3, we used a similar quiz to the one of the stage 2, but the questions were formed to acquire personal behavioural data, e.g., how many fruits did you eat yesterday? Finally, for stage 4 a rule-based goal selection engine was developed based on our traffic light decision scheme, according to the answers given in the personal behaviour questions of stage 3. The goal requiring more attention (e.g., eat at least 3 fruits/day), is announced by the robot as the child's mission for next week (i.e., weekly re-assessment).

[1] Anki Cozmo robot: https://anki.com/en-us/cozmo.html

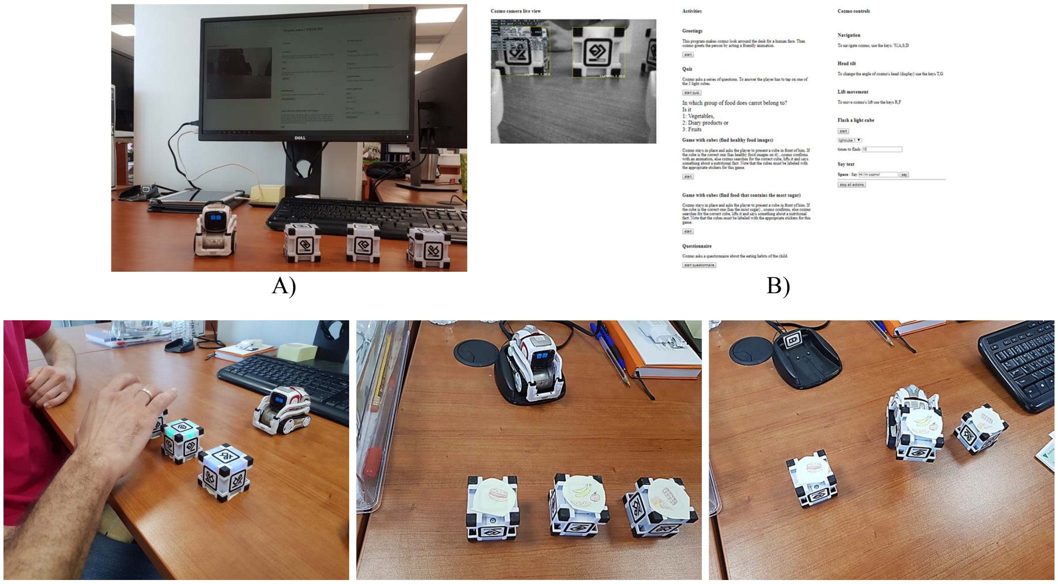

Fig. 2. A) Experiment setup: Cozmo robot and cubes, tablet computer, and PC, B) PC application, C) Participant interacting with cubes to answer a question asked by the robot, D) Robot game "Identify healthiest food", E) Robot lifting a cube (healthiest food)

III. RESULTS

We conducted an experimental study to explore the usefulness and usability of the proposed platform. 10 participants (6 male, 4 female) were recruited within the facilities of the Centre of Research and Technology Hellas, Thessaloniki, Greece, and agreed to participate in the study. The average age of the participants was 33 years (range 27 - 44). All participants were researchers in information and communication technologies and half of them had also experience of teaching for children.

The participants were initially informed about the concept of the study and the functions of the platform, and subsequently they proceeded with interactions with the robot through games and quiz as described in our technical implementation. The experiment setup involved the Cozmo robot and the cubes, one Android tablet computer to pair with the robot, and a PC with an interface for executing the games, enabling participants to see in text instructions, questions provided by the robot, as well as reward and motivation messages (Fig. 2). Two researchers (AT and DE), supervised the interaction processes, providing also instructions to the participants on how to play the games, whenever necessary. Participants were then asked to complete the System Usability Scale (SUS) questionnaire [12], a tool based on 10 questions of mixed positive and negative tone, all with a response scale from 1 (strongly disagree) to 5 (strongly agree), which measures usability and has been proven to be reliable. 5 additional questions were also asked:

#1. *From 1-5, how much did you like the robot?*

#2. *From 1-5, how much did you like the designed games for child-robot interactions?*

#3. *What was the best aspect of the social robot-based platform that you used?*

#4. *What was the worst aspect (requiring improvement) of the social robot-based platform you used?*

#5. *Do you have any other comments or suggestions?*

The SUS score was 93.8, which indicates an excellent usability of the proposed platform. The items which ranked highest in SUS were "I thought there was too much inconsistency in this system" which received a score of 1 ("Totally disagree") from all 10 participants, and the item "I would imagine that most children would learn to use this system very quickly" which received a score of 5 ("Totally agree") from all participants. The item which ranked lowest in SUS was "I found the system very cumbersome to use", which had an average score of 1.8 (leaning towards "Disagree").

In question #1, the average score was 4.8 and in question #2, the average score was 4.5. This shows that participants liked both the robot and the designed games, and thought that these would be both useful and entertaining for children, towards better adherence to healthy habits and the prevention of childhood obesity. Interestingly, 3 participants commented that the proposed platform could be used even by adults. In open-ended question #3, half of the participants answered that the robot reactions were the best aspect of the platform, e.g., when the robot blinks its eyes, says "well done" and moves around when a right answer to the quiz is given. Other aspects of the platform which were considered to be the best by the participants were: Child-robot interactions in general (2 participants), looking for correct cubes and their lift (2 participants), and the useful guidance provided by the robot through voice when somebody answers wrong (1 participant).

In open-ended question #4, 8 participants mentioned the robot voice as the feature of the platform which needs most improvement. This was because the robot voice was considered to be too "artificial" and "synthetic", and participants felt that children would not be able to understand it. However, all questions and responses from the robot were also shown in text within a PC interface displayed on a large screen, to enable smooth gameplay.

Finally, in open-ended question #5, there were interesting remarks indicated by the participants for future work. 3 participants mentioned that the PC interface displaying the instructions, questions, and answers, should be more “childish”, enabling to attract the attention of the children, and improve their understanding of the way the games are played. This could be done for example through the addition of photos. One participant mentioned the importance of providing motivation to use the platform in the end of the interactions with the robot, e.g., through a message “See you next week!”, delivered through voice by the robot. Another participant mentioned that more games for child-robot interaction could be developed, reporting as an example the co-construction of a food pyramid by the child and the robot.

IV. Discussion

We presented the design, development and evaluation of a social robot-based platform for childhood obesity prevention. A commercially available, programmable robot was adopted, and a series of educational and entertaining games for child-robot interaction were designed. Through taking advantage of sensors, such as a camera for face and object detection, and accelerometers for recognition of touch on objects (i.e., cubes), as well as in-built capabilities of the robot such as text-to-speech synthesis and eye animations, our aim was to develop an interactive and highly engaging platform.

Our exploratory study showed high ratings of usability of the proposed platform as indicated by a very high SUS score. Overall, the participants (healthy adults) showed enthusiasm when interacting with the platform and provided positive feedback, e.g., the platform was quick to learn and not inconsistent, the designed games were enjoyable, the robot reactions were considered to be the best aspect of the platform. These results show the potential attractiveness of the platform to the children, which is important towards increasing their interest in acquiring healthy behaviours.

According to the responses of the study’s participants, our social robot-based platform can be improved. In this direction, our future work involves the design of additional child-robot games for experiential learning and education towards engagement with healthy behaviours and the prevention of childhood obesity. We plan to design those games according to pedagogical principles, and following the international guidelines for diet and physical activity. Furthermore, the addition of speech recognition in the proposed platform would enable improved interactions between the robot and the child through dialogue. In this context, the collection of behavioural data in terms of personal habits, would become more straightforward on the long-term horizon. In a next step, the analysis of these data-sets could indicate the behaviours which need attention and guidance, or reveal potential risks through the deployment of computational models and decision support systems [13].

In conclusion, we have presented a platform which utilizes a social robot to interact with children and educate and guide them towards preventing childhood obesity. At this stage, our prototype implementation constituted a technical proof-of-concept which was evaluated by adults. It is evident that further longitudinal studies with children are now needed to explore the effectiveness of our platform in promotion of healthy habits. Nevertheless, preliminary evaluation results show the feasibility and potential of such platforms for the promotion of a healthy living.

Acknowledgment

The study was supported by the European Union`s HORIZON 2020 Programme (2014-2020), under ID n° 777082, and from the Brazilian Ministry of Science, Technology and Innovation through Rede Nacional de Ensino e Pesquisa (RNP) under Ocariot.

References

[1] M. Simmonds *et al.*, “The use of measures of obesity in childhood for predicting obesity and the development of obesity-related diseases in adulthood: a systematic review and meta-analysis,” *Health Technol. Assess. (Rockv).*, vol. 19, no. 43, pp. 1–336, 2015.

[2] World Health Organization, “WHO | Childhood overweight and obesity,” *WHO*, 2017.

[3] E. B. Tate *et al.*, “mHealth approaches to child obesity prevention: successes, unique challenges, and next directions,” *Transl. Behav. Med.*, vol. 3, no. 4, pp. 406–415, 2013.

[4] T. Turner, D. Spruijt-Metz, C. K. F. Wen, and M. D. Hingle, “Prevention and treatment of pediatric obesity using mobile and wireless technologies: a systematic review,” *Pediatr. Obes.*, vol. 10, no. 6, pp. 403–409, 2015.

[5] O. Mubin, C. J. Stevens, S. Shahid, A. Al Mahmud, and J.-J. Dong, “A review of the applicability of robots in education,” *Technol. Educ. Learn.*, vol. 1, no. 1, pp. 1–7, 2013.

[6] O. A. B. Henkemans *et al.*, “Design and evaluation of a personal robot playing a self-management education game with children with diabetes type 1,” *Int. J. Hum. Comput. Stud.*, vol. 106, pp. 63–76, 2017.

[7] T. N. Beran, A. Ramirez-Serrano, O. G. Vanderkooi, and S. Kuhn, “Humanoid robotics in health care: An exploration of children’s and parents’ emotional reactions,” *J. Health Psychol.*, vol. 20, no. 7, pp. 984–989, 2015.

[8] T. Belpaeme, J. Kennedy, A. Ramachandran, B. Scassellati, and F. Tanaka, “Social robots for education: A review,” *Sci. Robot.*, vol. 3, no. 21, p. eaat5954, 2018.

[9] E. Short *et al.*, “How to train your DragonBot: Socially assistive robots for teaching children about nutrition through play,” in *The 23rd IEEE International Symposium on Robot and Human Interactive Communication*, 2014, pp. 924–929.

[10] F. B. Hu *et al.*, “Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire,” *Am. J. Clin. Nutr.*, vol. 69, no. 2, pp. 243–249, 1999.

[11] K. F. Janz, E. M. Lutuchy, P. Wenthe, and S. M. Levy, “Measuring activity in children and adolescents using self-report: PAQ-C and PAQ-A.,” *Med. Sci. Sports Exerc.*, vol. 40, no. 4, pp. 767–72, 2008.

[12] A. Bangor, P. T. Kortum, and J. T. Miller, “An Empirical Evaluation of the System Usability Scale,” *Int. J. Hum. Comput. Interact.*, vol. 24, no. 6, pp. 574–594, 2008.

[13] A. Triantafyllidis *et al.*, “Computerized decision support for beneficial home-based exercise rehabilitation in patients with cardiovascular disease,” *Comput. Methods Programs Biomed.*, vol. 162, pp. 1–10, 2018.