Tangible Educational Toys for Children with Type-1 Diabetes

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Abstract
The aim of this research is to (i) provide diabetes educators with an interactive tool for age-appropriate, fun and engaging diabetes education, (ii) inform the research community about the effectiveness of tangible toys for health education and most importantly (iii) empower children with type-1 diabetes to have a more active role in the management of their condition and potentially a better quality of life. This paper presents the stakeholder centred design of tangible educational toys for children, aged 3 to 8 years old, with type-1 diabetes. These toys were co-designed with the help of diabetes professionals and are based an initial requirements gathering and scoping phase with all the diabetes stakeholders (clinicians, parents, children and policy makers). The paper concludes by discussing how the system is being built and how it will be evaluated in the clinic context.

Author Keywords
Tangible Interface, Diabetes Education, Children

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Introduction
Diabetes is serious long-term condition whose management requires frequent monitoring, insulin dose calculations and decisions by balancing several factors [5], which makes it very hard for young children to understand and manage. Moreover,very young children are often discouraged to take initiative in the management process (due to the high risk of the consequences) a fact that initially makes them passive receivers of instructions. Younger children often cannot have access to information about their condition alone because they do not have sufficient literacy skills to access the wealth of printed and online information. Transitional from this passive role into becoming a more active participant in self-management of conditions such as diabetes requires tools that support the child in learning about and engaging with their long term condition early on.

Diabetes education can be the source of information that can help young children fundamentally understand the factors that influence their condition and how those interact with each other [1]. For ages 3 to 8, education needs to be age- appropriate and focus more on practical information and skills training [7]. Nonetheless, children do not always enjoy the conventional diabetes learning methods (a classroom style learning with the use of printed materials) which are currently employed, since they are often very passive, lack fun and most of the time are not age-appropriate [2, 7].

Figure 1: The first diabetes educational video games, for SNES. Left: *Captain Novolin*-1992. Right:*Packy and Marlon*-1995

Figure 2: PC games. Up:*Starbright Life Adventures*- PC CD (1999), Middle:*Dbaza Diabetes Education for Kinds*- PC CD (2003), *Ranj's GRIP*- Online Flash (2008)

Industry and research communities have both over the years introduced educational video-games as a more attractive and engaging alternative [4]. However, despite the relatively large number of these becoming available, very few are clinically validated and only a few of the games satisfy the educational needs of children with type-1 diabetes [4].

Background

The way children create mental models and assign meaning to actions and concepts is gradual. Children start by automating processes which then will be acceded to the symbolic level and eventually create the appropriate mental models [10].

The focus on the symbolic level accompanied with the idea that young children construct knowledge through physical interactions with the world (Hands-on activities) has long being studied, even from the early 1800s. Pestalozzi [12] was the first pedagogist to point out the advantages of hands-on activity and learning by doing; he stated that "*things should go before words and concrete before abstract*". Based on his ideas, other pedagogists such as Fröbel and Montessori created tangible educational toys that allow children to build real world objects or structures and model more conceptual and abstract structures respectively [15].

Piaget, in the 20th century, was the first to theoretically frame the concept that, children learn by interacting with their environment and must first construct knowledge through concrete operations and based on those build formal operations [13].His theory, known as constructivism, posits that exploration and problem solving create the context in which learning occurs in the pre-operational (3 to 8) children stage.

The mass appeal of video-games and the development of their educational aspects, led the researchers and the industry in the creation of video games also for diabetes education. Some of these games are presented in Figures 1 - 3. Most of these games have focused on children older than 8 years old with basic literacy and thus are not accessible by younger children. Moreover, such approaches, most of the times, are not designed to be used in The clinical setting, require the possession of a special device by the family, do not necessarily promote collaborative learning and may require the over-exposure of the child to the device.

Thesis Statement

Tangible educational toys can be used in a clinical setting to empower children with type-1 diabetes to play a more active role in their condition's management, by making them active learners and allowing them to learn in more age-appropriate, fun and engaging ways.

Research Questions

1. Can tangible educational toys improve the in-hospital education of children 3 to 8 with type-1 diabetes?
2. Can tangible educational toys for diabetes enhance the diabetes management skills of children 3 to 8 with type-1 diabetes?
3. How will tangible educational toys for type-1 impact the other diabetes stakeholders (parents, clinicians, educators and friends)?
4. Can tangible educational toys for diabetes continue to support children with type-1 diabetes in their day-to-day (out of hospital) diabetes management?

Research approach and methods

The project went through different design phases before it was finalised. The objective of this project from the beginning was to have a holistic perspective in the design ap-

Figure 3: Feature phone games. From top to bottom: *Insulot* 2005 - slot game for carbohydrates measuring, *Egg Breeder* 2004 - Breed a diabetic egg until it hatches, *Detective* 2004 - Help a diabetic detective to catch a villain, *Building Blocks* 2004 - Block building game

proach were the needs and requirements of all the different stakeholders would be meet. Hence, a user-centred design approach was chosen, taking into account the specific constrains (eg time-scale of a PhD). The methodology used could be described as an agile adaptation of the "contextual design" [3] with some "task-centred system design" [8, 6] aspects. This choice was made because I believed that the system had to be design with the different stakeholders and based on the specific context (the clinical setting). A diagrammatic representation of the process can be seen in Figure 4

The first step in this process was to gather the requirements of the different stakeholders and determine the scope of the project. Therefore, a set of semi-structured interviews with different diabetes stakeholders (parents, clinicians and Scottish diabetes policy makers) was conducted. In order to get more participation from parents an online questionnaire was distributed through online support groups.

It was found that the informal education delivered by family and friends is lacking standardised educational practices and may be delivered through age-inappropriate materials. Hence, the onus for in depth diabetes education is on the clinicians. Surprisingly enough, the clinicians in their struggle to provide age-appropriate education came up with a very interesting approach to diabetes education. They are using a set of plastic food toys to educate about the potential impact of each food to the condition, whereas the rest of the diabetes concepts are explained with the use of leaflets.

The next step in the process was to investigate and understand the clinicians' approach to education (plastic food toys), and thus a contextual inquiry was conducted. The contextual inquiry was split into two sessions. Initially I interviewed a diabetes nurse in the clinic and she explained the whole educational process, the materials they use and described in detail how and why they are using the plastic food toys. In the second session I participated in a formal educational session for families which children had been recently diagnosed with type-1 diabetes. This session had some interactive elements and looked like a workshop. A doctor, a nurse and a dietician where presenting the different aspects of diabetes to the families. The participants where at some point split into two groups (children and parents) and the children where taken to another room. The children where introduced to the basic food categories (which where explained with plastic food toys) and were also asked to draw body depictions with the endocrine system in order to understand how their body works (at least what is related with diabetes). It was prominent that the clinicians where trying to use concrete representations, of the different concepts, in a playful way in order to get the attention of the children but also describe real world notions and objects (eg. food and endocrine organs) in a more intuitive way.

Nonetheless, there were also limitations with this approach. Initially this style of education and the tools used in it was not interactive, thus making children passive receivers, and also according to the clinicians, the children were getting bored easily. Moreover, the education was covering only food intake and endocrine system leaving out the other important aspects (insulin, exercise and glucose monitoring) which the children had to learn by experience.

After these requirements gathering and scoping phases, it was prominent that a new approach to diabetes learning for children had to be employed; an approach that is based on the developmental psychology, overcomes literacy problems and is more fun and engaging. The technology that is relevant to the current educational practices, combines the engagement of video-games and the learning effects of con-

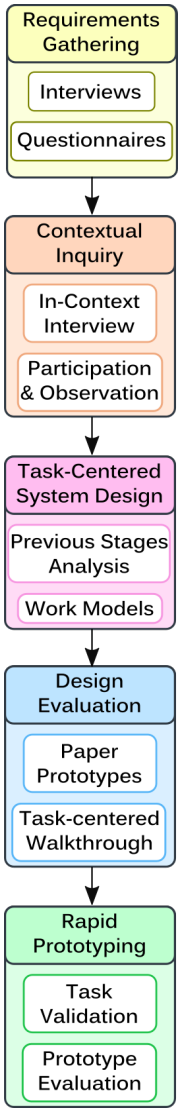

Figure 4: The design process

structivism is tangible interfaces [11]. Tangibles interface games are proven effective in educating young children and thus I decided to implement the game as a tangible educational game that will provide a holistic approach to diabetes education by teaching children about all factors related to diabetes in a more interactive and intuitive way.

Before I started creating any prototypes I transcribed and analysed qualitatively all the interviews for emerging themes. Moreover, I created different diagrammatic “work" models (flow, artefact and cultural) in order to understand the eco-system in depth. Once I was done with the analysis I distinguished the educational requirements and created educational scenarios, tasks and interactions based on them.

The subsequent step was to present the designs to the clinicians and evaluate them. Though the process of task-centred walktrhougs they evaluated the design through storyboards with the use of family personas. Finally, the system outline and specific ideas about each task and 2D graphics about the design, were evaluated in a focus group session where two clinicians, four children and five parents commented and proposed ideas about the tasks, the 2D graphics and the system outline.

The final step was to produce two software prototypes that were encapsulating all the results and design decisions of the previous stages. Those prototypes were tested again by the clinicians in one focus group session for each prototype. The clinicians gave their final feedback on the prototypes, based on which the final system is based.

The final system would be a tangible user-interface game which will have five main components, each one interacting with the others as shown in Figure 5:1) an interactive “diabetic” figure with a display in its abdomen, 2) glucose-monitor toy, 3) physical plastic food toys, 4) a plastic workout toy (eg dancing mattress) 5) a plastic toy syringe.

Each component is going to be related with one of the most important factors about diabetes;namely, the child’s endocrine system, blood glucose, food intake / carbohydrates, exercise and insulin treatment respectively. Through the gameplay, the child will explore the different factors and how those interact with the condition. Hence, it will get a more holistic idea about the diabetes “equation” and how it can be managed. All aforementioned components are able to interact with the “diabetic” figure through wireless technologies (RFIDs, Bluetooth). The game combines multiple feedback channels (audio and visual) and exploratory learning. The game does not require literacy skills, as it is played through direct manipulation [11].

Reflection upon actions
One of the key features that will reinforce children’s learning and will help the clinicians understand children’s misconceptions is the feedback from the game [9]. The game will frequently require from the children to stand back from the learning and reflect upon their actions. Moreover, the game could be played collaboratively. This way children would have the opportunity to see someone else’s perspective, negotiate and be aware of actions in a more objective way.

Narrative game - exploratory game
The game will have a narrative nature and will guide the child through the typical management of the condition. The child will be asked to help the “diabetic” mannequin manage its condition in everyday scenarios (eg. hypoglycaemia in school or sports, meal preparation etc). This way the children would relate to the mannequin and see how their choices (food, insulin and workout) impact the condition without putting themselves into harm.

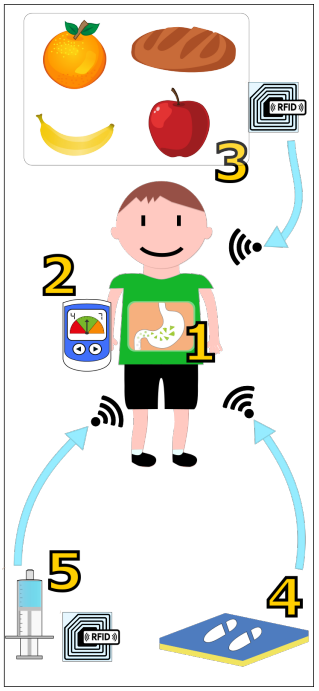

Figure 5: A depiction of how the game would look like. The three input components (food toys, syringe toy, work-out toy) would interact with the "diabetic" mannequin. Audio and visual feedback for the child's actions would be given from a display in the abdomen and speakers inside the mannequin,

Physical interaction
The concreteness of the toys and the physicality of the interface, will promote a more realistic interaction, similar to the actual management. Children will have to choose the proper foods, provide insulin through a syringe and physically exercise (by using the work-out toy). This way they will see how real world actions impact the condition.

Active approach to management
Through this kind of gameplay, the children can have a more active approach in the condition's management and potentially enhance problem solving.

Projection of emotions
The fact that the system will have a human-like figure with diabetes, which the children will help by managing its condition, will help them project their emotions to the figure. The feeling of empathy created from such an interaction can have positive effects on the child's mentality [14].

Next steps
The first working prototype of the game will initially be evaluated for usability and the feedback from the usability evaluation will guide any refinements and lead to the final game. After I fully design and implement the system, I am planning to do an evaluation of the effectiveness of the tool. The options so far for the evaluation of effectiveness are: (i) Evaluate in regular educational sessions with the presence of a clinician (ii) Evaluate in sessions where parents will help their children. (iii) Place the system in the diabetes clinic's waiting room and observe how children will freely interact with it. (iv) Evaluate in a school, where a child with diabetes is going to be explaining his/her condition to the classmates.

The key challenge with the evaluation of effectiveness is what exactly will be measured. In order to prove the effectiveness of such a system many potential measurements can be employed, such as educational effectiveness, engagement, long term support, perceived effectiveness etc. Moreover, it is hard to compare the system with the existing approach because the educational targets are fewer. Also, it is difficult to collect subjective measurements from children in a systematic way. Lastly, the participation in might not be as expected and thus, the distortions in the results might be high.

Contributions

A practical contribution of the preliminary study is that the prototypes of the design phase (2D graphics) are currently used in the children's hospital in order to illustrate the basic concepts to the children. The clinicians found them more age-appropriate than the materials they were using. Even though such a contribution cannot be cited, it is valuable for the local diabetes "*eco-system*" and reinforced my beliefs for the importance and acceptance of the project.

The expected final contributions of this project are more important and meaningful. Initially, a tool that is going to help different type-1 diabetes stakeholders, and will potentially have use in different settings (classroom, home, clinic). It will be a low cost platform that could also be used for other similar long-term conditions, such as obesity, or in general to teach health and well-being related concepts to young children.

Another expected contribution is that the evaluation of the game will give valuable insights to the research community, about the use of tangible toys for health education, which is a relatively unexplored field. Lastly, it will comprise of a tool that will empower young children with diabetes to manage their condition and potentially have a better quality of life.

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