Let them play: experiences in the wild with a gamification and coaching system for young diabetes patients

Rieks op den Akker
Human Media Interaction
Enschede, Netherlands
h.j.a.opdenakker@utwente.nl

Randy Klaassen
Human Media Interaction
Enschede, Netherlands
r.klaassen@utwente.nl

Kim Bul
Coventry University
Coventry, UK
k.bul@coventry.ac.uk

Pamela M. Kato
Coventry University
Coventry, UK
pam@pamkato.com

Gert-Jan van der Burg
Hospital Gelderse Vallei
Ede, Netherlands
vdburg@zgv.nl

Pierpaulo di Bitonto
Grifo multimedia Srl
Bari, Italy
p.dibitonto@grifomultimedia.it

ABSTRACT

In this paper we describe a platform that integrates gaming and coaching for adolescent patients with type 1 diabetes and results from user evaluations of the platform. The purpose of the platform is to support patients in diabetes self-management through educational game playing, monitoring and motivational feedback, and to support patients' care givers. We describe the design of the platform referring to principles from health care, persuasive system design and game design. The virtual coach is a game guide that can also provide personalized feedback about the user's daily care related activities which have value for making progress in the game world. We report about user evaluations in the wild which revealed that some assumptions made about how users are connected to the platform were not satisfied in reality, resulting in less optimal user experiences. We discuss challenges with suggestions for further development of integrated pervasive coaching and gamification platforms.

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (HCI): Miscellaneous

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gamification; digital coaching; diabetes education; self-management; user evaluations

INTRODUCTION

In this paper we present an instantiation of the PERGAMON platform developed in the European PERGAMON Horizon 2020 project. The multi-device platform is tailored to both patients' needs and health care system services. From the healthcare perspective, represented by the pediatric department of the Dutch hospital, Gelderse Vallei, the aim was to see how gamification and digital coaching could be integrated into the continuous care of patients with chronic conditions. Expertise was further brought in by the Human Media Interaction Group of Twente University (research and development in digital coaching systems [21]), the Serious Games Institute of Coventry University [20], AISolve London (sensor network, mini games), and Grifo Multimedia, the SME leader of the project (technical game development and integration). The implementation of the platform, the "Tako Game", that we describe here targets adolescents with Type 1 diabetes aged 12-18.

Self-management is of key importance in the successful treatment of young people with chronic conditions, such as Type 1 diabetes (T1D), a condition in which the patient needs daily insulin treatment, for example, because their body fails to produce this hormone. Goals for the management of T1D include achieving optimal glycemic control, avoiding acute complications, and minimizing the risk of long-term micro vascular and macro vascular complications. Self-monitoring of blood glucose (BGM) is one of the most important activities in managing diabetes. Research repeatedly showed that adherence to BGM is linked to glycemic control in pediatric T1D [16][26][36]: the more frequently the patient measures his BG, the more his or her BG will be within acceptable and appropriate levels. Despite advances in technologies that support BGM, frequent measuring is still a burden for many children and adolescents [32]. Adherence, i.e., the degree to which the person's behavior corresponds with the *agreed* recommendations from a healthcare provider, is a key factor in the successful treatment of chronic conditions. One of the adherence challenges with T1D is motivating and helping these patients to measure their BG at regular times every day. Digital coaching systems that monitor the users' BG can send reminders and help the patient to adhere to a personalized and clinically appropriate medical regime. But to function properly, these systems need data from the user, which often requires additional actions on the part of the user. These systems are often not successful in increasing adherence in

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the long run. According to self-determination theory it may take many months before external motivation to change daily behaviour becomes internalized and part of daily routine [38]. Hence there is a quest for ways to motivate the user to adhere to their treatments through the use the digital coaching system as long as blood glucose control is not done fully automatically. Gamification techniques and serious games have been introduced as possible means to motivate patients to sustain adherence to medical treatment [20]. As game designers we use game elements to "more or less deliberately direct players into patterns of behaviour that can be anticipated" [18]. The PERGAMON platform is a gamification platform that integrates educational gaming and coaching. It gamifies self care related activities so users are rewarded for making progress in the game world. The virtual coach can keep track of users' daily BGM, physical activity, food intake and send reminders and motivational messages when the user forgets to follow recommendations agreed upon with their healthcare professional. The coaching system rewards behaviour that corresponds to personalized goals. The platform provides a secure way for message exchange and data sharing between patients and their care givers.

After placing our work in the field of gamification and serious games for diabetes care we present basic design principles of the PERGAMON framework. We then describe user evaluations, present results, draw conclusions and discuss future challenges.

RELATED WORK: GAMES FOR DIABETES CARE

A growing number of mobile diabetes apps is available to assist patient in diabetes management. The apps typically log blood glucose readings and some allow users to log carbs, food, medication, weight and more. Some apps target young T1D patients and use elements of gamification. Some apps let children guess their BG level. In DiaBetnet children are awarded points based on how close their guess was. In the mobile game, DIAL, a group of children (8-18) obtained a mobile device with an integrated motivational game in which the participants could guess a BG level following collection of three earlier readings [23]. In a 4 week experiment, the game group sent significantly more glucose values than the control group that did not have the game. Use of a motivational game appears to increase the frequency of monitoring, reduce the frequency of hyperglycemia, improve diabetes knowledge and may help to optimize glycemic control.

Eng et al. [14] reviews apps from a medical perspective and concludes that although mobile health apps have great potential for improving chronic disease care, they face a number of challenges including lack of evidence of clinical effectiveness, lack of integration with the health care delivery system, the need for formal evaluation and review and potential threats to safety and privacy.

Brzan et al.[6] reviewed sixty-five apps for diabetes and concluded that fifty-six of these apps *did not meet even minimal requirements or did not work properly*. They report about a qualitative study in young adults with the objective to explore their experiences and views on apps related to health behavior change, including their perceptions of various features and their willingness to use these apps. Some participants in their study *were not motivated enough to regularly and precisely use the apps in making healthy lifestyle changes*, a recurring issue in many studies.

While a wide selection of mobile apps is available for self-management of diabetes, current research suggests that most do not meet basic requirements for these type of medical applications. Where user centered design and tailoring to the individual user are more and more seen as an important requirement for usability and effectiveness of diabetes care apps [30], most apps, according to Breton, are not developed by medical experts and contain insufficient evidence-based content [3].

Various studies have tried to address the issue of low adherence and increasing motivation with diabetes apps by introducing elements from game-based approaches or "gamification" into diabetes initiatives, such as for self-monitoring and diabetes education. Educational games in diabetes care dates back to the 90s. Several studies using random control trials, e.g. Brown et al. [5] and Fuchslocher et al. [15], showed diabetes related content explicitly presented in games improves diabetes self management in juveniles. Lieberman [24] describes 14 diabetes self-management video games. In a Special issue on Games for Diabetes Theng et al. [34] provides a review of evidence about the efficacy of video games and gamification in diabetes self management.

Acceptability and performance of a blood glucose meter coupled with a gaming system was assessed in a sample of children, adolescents, and young adults with T1D [22]. The system is based on a blood glucose meter that allows for connection of the meter to a Nintendo game. Similar to the Tako Game presented here, users receive reward points that can be transferred from the meter to the video game, allowing access to new levels of play and mini-games. Rewards are based on frequency, timing and results of blood glucose testing. Health care providers can also set personalized target ranges in the meter to help patients reach glucose goals. The majority of health care providers agreed that *the coupled system would solve a problem in diabetes management, would fulfill a need in diabetes management, and would motivate subjects to test their blood sugar*. However, the observed increase of use in the home situation compared to the lab situation was due to the users wanting to have more advanced games.

AlMarshedi et al. discusses the validation of a framework for gamification of self-management in diabetes care. Results using a mixed method approach including interviews with experts indicate that gamification might improve the self-management of chronic illnesses, such as diabetes [1]. A rationale for using games for serious purposes like health is their ability to motivate and facilitate social encounters relevant in health care [18]. Use of games or gamification in health behaviour change programs might thus be a good way to intrinsically motivate users to expose themselves to and continually engage with these programs (Baranowski et al. 2008 [2], Thompson et al. [35]). Gamification is using elements of game design [12], i.e., points, leader boards, levels, competitions, rewards, achievements, mini-games, goals, experience points, rules, narrative, graphics, imagination, role identification, or setting step-wise challenges in pursuit of a goal. In serious games elements of game design are used to help the user learn to reach a non-game goal. The ultimate goal is to foster intrinsic motivation for learning and maintaining desired behaviour [10]. A systematic review by Edwards et al. [13] examines the use of behaviour change techniques in smartphone games aimed at changing health-related behaviours. Charlier et al. [9] reports a review of RCTs assessing efficacy of serious games in improving knowledge and self-management in young people with chronic conditions. From nine studies the general conclusion is that educational video games improve knowledge and self-management. Johnson et al. [19] identified seven potential advantages of gamification from existing research and conducted a systematic literature review of empirical studies on gamification for health and well-being, assessing quality of evidence, effect type, and application domain. Due to the relatively small number of studies and a lack of studies that compare gamified interventions to non-gamified versions of the intervention, it is hard to draw general conclusions about the efficacy of gamification in digital health interventions. Deacon [11] comes to a similar conclusion: *(..) there is a lack of systemic analysis to inform future (game-based) intervention design.*

We can conclude from our investigation into the history of digital games for health that different subsets of game elements implemented in the Tako Game are present in earlier video games and apps for T1D patients as materialization of various behaviour change techniques. The Tako Game integrates the game elements and virtual coaching with a well designed system of main game and mini-games based on an ontology of tasks, sub-goals and goals. Moreover, contrary to many systems medical content and coaching messages are tailored and personalized.

DESIGN PRINCIPLES FOR GAMIFICATION

Special consideration was given to basic principles of health care in the design of the system. Specifically, values of care, from the patient's perspective as well as from the perspective of the care givers, played a central role in determining design, especially regarding what techniques and content the system implemented, how the system communicated with the user, and how the system treated personal information. For a discussion of care values in the context of design for care, please see [37]. The gamified platform involved introducing intelligent systems to users that could to some extent take over the role of human care givers. This raised issues of responsibility in the design of the platform regarding a general responsibility as designers for insuring that care values were protected. In our view a system can never take away the responsibility from the human user, nor can the human give away responsibility to a technical artifact (including "social" robots). On the contrary, the design aims at supporting the patient in becoming a responsible person in their self care by providing the patient the means, along with supportive motivation, to make a well-informed decision. *Tailoring* to the individual user and his or her social and intellectual abilities was therefore an important requirement for the design. The aim of self care is not for technology to completely replace the human care system, but to support and enhance it. The PERGAMON system was designed to be integrated in the care and treatment of young patients by the medical care givers, e.g., pediatricians, diabetes nurses, and informal carers. Patient's *credibility* of the system depends on how *trustworthy* the medical experts are that provide input into the design of the system. Educational goals and targets of diabetes self-management formulated by diabetes care organizations were used to drive the content and design of the system as a whole, as well as for the specific themes of the games in the system. Specifically, these goals (diabetes educators) were balancing energy through medication intake, healthy eating, being physical active, learning how to monitor blood sugar levels, coping with high and lows of BG and how to reduce risks associated BGM. The system guides the individual and establishes together with the user specific, measurable, attainable, realistic, and timely (SMART) goals [7].

The design of a behaviour change support system for health interventions[28] involves the implementation of several behaviour change techniques (BCT), such as "feedback and monitoring", "reward and threat", and "social support". A behaviour change technique (BCT) is *"an observable, replicable and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour"* [8]. BCTs are based on socio-psychological behaviour theories, e.g., Goal-Setting [25], Self-Determination Theory [31]. BCTs were integrated into the Persuasive System Design Model (PSD) for behaviour change support systems [28] that we use to describe the system's design. The PSD model has four "categories": primary task support (PTS), dialogue support (DS), system credibility support (SCS) and social support (SS), each with a number of *design* "principles" (to be distinguished from the *moral* principles of health care). Key aspects of BCTs were integrated into the PTS, e.g. "self-monitoring", to the category DS (e.g. "rewards") or to the category social support (e.g. BCT "provide information about others approval" and "normative influence". Although Abraham et al. [8] presents 26 BCTs, the principles in the category of System Credibility Support in the PSD model do not occur in the BCTs listed. This is understandable because the PSD is intended for the design and evaluation of a *technical* system, not human beings *per se*. These systems function as more or less autonomous entities in situations where the medical care giver is not immediately present for the user. Also, by their very nature, technical systems have "abstract users" so that for the system designer *tailoring* and *personalisation* become a concern (partly solved by explicit user models and use of "persona" in the design process) where treatments by human care givers and coaches (different from rule following machines) are expected to tailor their treatment to the individual patient.

Some of the design principles of the PSD model are implemented in our system by means of specific "game elements" (which encompass game mechanics, themes, game characters, challenges, rewards) from game design [18]. For example, the principles of *reduction* and *tunneling* in the PTS category of the PSD model are materialized by dedicated learning tasks in different mini-games and by distinguishing different reachable goal levels. Other principles, namely in the category DS of the

PSD model are implemented in actions of the virtual coach: *praise, rewards, reminders, suggestions* as well as by various game elements. *Similarity* and *social role* are materialized by game elements that aim at identification with the main character in the game as well as by the use of a similar character for the virtual coach.

The educational goals for diabetes care (e.g., BCT: "provide information on consequences" [8]) are implemented in the adventure game, called the*Tako Game*, in particular in a number of integrated educational mini-games and by educational elements such as videos. The Tako Game is a "pervasive" game in the sense that it expands the "magic circle" of play [18][12]: the border between game world and reality is blurred by making daily self care activities relevant in the game.

PERGAMON: A FRAMEWORK FOR GAMIFICATION, SENSORING AND VIRTUAL COACHING

The PERGAMON framework allows the creation of behaviour change support systems [27] that combine serious games (a main game and some mini games), virtual coaching and real-time monitoring of daily life activities via sensors. The typical system created with the PERGAMON framework consists of a web application (website), an Android application for gathering data from sensors, a Android webapp to view the PERGAMON website via a Android device and an Android Unity application for the games. The framework consists of five key components (Figure 2):

- Ground Layer (the central data hub)
- Sensor Network
- Gamification Platform
- Serious Game (the main game and the mini games)
- Virtual Coach

Figure 2 presents the architecture of the PERGAMON framework. The Ground Layer has a central place: it stores data from the other components and makes the data available to all connected components via APIs. Communication between the different components and the Ground Layer are over secure HTTPS connections and basic authentication is needed to access the APIs. The other components in the PERGAMON framework can read, write, update and delete data in the Ground Layer.

The Sensor Network component is responsible for the connections between the different sensors used to monitor the users of the system and the PERGAMON framework. The Sensor Network is running on an Android device (smartphone or tablet) and turns it into a sensor hub to which different devices can be connected. The architecture of the Sensor Network makes it possible to add new devices and services in an easy and modular way. Compatible sensors and services connected to the Sensor Network will automatically record data. The Sensor Network will gather the recorded data, process the data and push it to the Ground Layer component. The Sensor Network also provides the possibility for users to enter data manually.

The third component is the Gamification Platform. Goals in the platform can be defined and created by the game designer using a platform designer's interface. Goals are realized by completing specific tasks that may consist of activities of the user in daily life or user actions within the platform. Goals achieved by the user In the PERGAMON framework are translated by the Gamification Platform into three different kinds of points: knowledge points, experience points and evolution points. The user needed to gain these points to continue to play the Serious Game.

The PERGAMON framework supports two different kinds of games. The main game is an adventure/puzzle game that can be played over a longer period of time. Users have to solve puzzles and levels to make progress in the game. Points (knowledge, experience and evolution points) are needed to continue the main game. In this way the main game is linked to the real world and other components of the PERGAMON framework. Mini games are of a different type. They are played in a shorter timespan and were designed to communicate certain educational objectives related to the chronic condition by means of game metaphors. Users were required to play the mini games to make progress in the main game. The games in the PERGAMON framework were developed in the Unity game engine and had the capacity to communicate with the Ground Layer of the PERGAMON framework.

The Virtual Coach is designed to "know" the personal objectives of each of the users as well as their achievements in the real world and in the game world. Please see Figure 1. The coach uses this information to assist the users in achieving their objectives by processing collected data and offering guidance in the form of reminders, notifications and suggestions about certain actions and events. The Virtual Coach component consists of a coaching engine and a graphical representation of the virtual coach [29].

Coaching rules defined in the coaching engine allowed for the analysis of data available in the Ground Layer derived from other components of the framework. The conditions and targets of the coaching rules are based on self-management behaviour as specified by healthcare professionals. The coaching rules are executed by triggers that are event or time based. When coaching rules are executed the Virtual Coach compares the data from the Gamification Platform to the user's personal goals. The result of these coaching rules can be a dialogue act of several kinds such as a suggestion (e.g., to play certain serious (mini-) games where the user can meet educational objectives) or a reminder or a notification (e.g., when goals are reached or users forget to do their measurements). The Virtual Coach is also able to send text messages and notifications to the website and to the Android application. By presenting the Virtual Coach as a cartoon-like character from the main game world, the coach connects the in-game world with the primary world of the user's daily care activities.

The Mystery of TIKI TAKO

The TIKI TAKO system for young T1D patients is an instantiation of the general PERGAMON framework. The characteristics of the TIKI TAKO system are presented in Figure 3 and Table 1. The Ground Layer of the TIKI TAKO system supports the storage of data and measurements about physical activity, glucose measurements, insulin intakes, and food. The Sensor Network of the TIKI TAKO system supports different channels and devices that are able to collect information

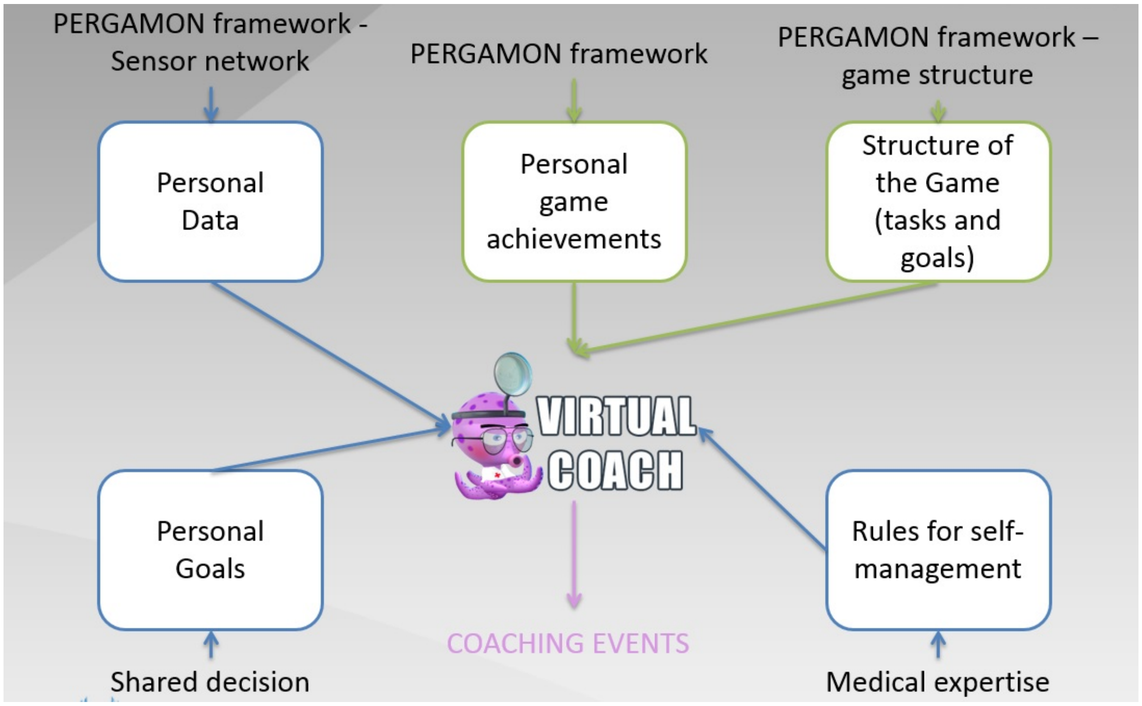

Figure 1. The knowledge and data source components used by the Virtual Coach of the PERGAMON platform for diabetes self-management

about daily life activities via sensors. It supports the Google Fit service which collects information about physical activity (number of steps and activity intensity). Other sensors compatible with Google Fit service could be used in the TIKI TAKO system to also collect data about physical activity. We used the Google Fit Pedometer (on the smartphone itself, or on an Android Wear smartwatch) and the Mi Fit Band as sensors. Also the services of iHealth are supported to collect physical activity or blood glucose measurements. Menarini blood glucose sensors are also supported to measure blood glucose. The Sensor Network also allows for manual input of information about diet, insulin and sleep.

There are five types of goals and tasks in the Gamification Platform of the Tako Game:

- "My Sugar" tasks relate to measuring blood glucose, reinforcing the relationship between diet and glucose levels, education about hypo and hyperglycemia or taking notes regarding insulin use.
- "Physical activities" are tasks related to diabetes and physical activity and sports such as setting a number of steps as a daily goal or learning about how to prepare to engage in sports.
- "Active life" tasks support the user to self-manage their diabetes in a more introspective way rather than overtly directing their activities. Examples are writing a to-do list to plan activities in a day or reviewing ones activity or BG data.
- "Website Activities" are tasks related to the use of the system and the website such as creating a profile or installing applications on the smartphone.
- "Mystery of TikiTako" tasks are related to the main game of the TIKI TAKO system such as how to continue in the game or how to finish a mini game.

The Serious Game component of the TIKI TAKO system consists of the main "Mystery of TikiTako" game and seven mini games. The main game is an adventure and puzzle game in which the player takes on the role of an investigator who tries to solve a mystery. The investigator also has T1D. The player progresses in the game by successfully directing the main character to control his diabetes and solve puzzles. This can occur through the mini games that have educational goals, such as how to do insulin injections or how to balance BG levels. The player can be supported in the games through text messages from the Virtual Coach or educational videos. Figure 1 provides an overview of data and knowledge used by the virtual coach component of the TIKI TAKO system.

USER EVALUATIONS

After a two week pilot test with seven T1D patients another group of 14 patients from the participating hospital in Ede tested the system over 6-8 weeks.

Goals

The user evaluation aimed to see how T1D patients experience the game. We used a mixed methods approach (i.e., direct observation, questionnaires, and semi structured interviews) to answer the following quetions: Do players like to step into the "magic circle" [17] and does striving for progress in the game motivate healthy behaviours? Do users appreciate the coaching messages? Do users find the educational films

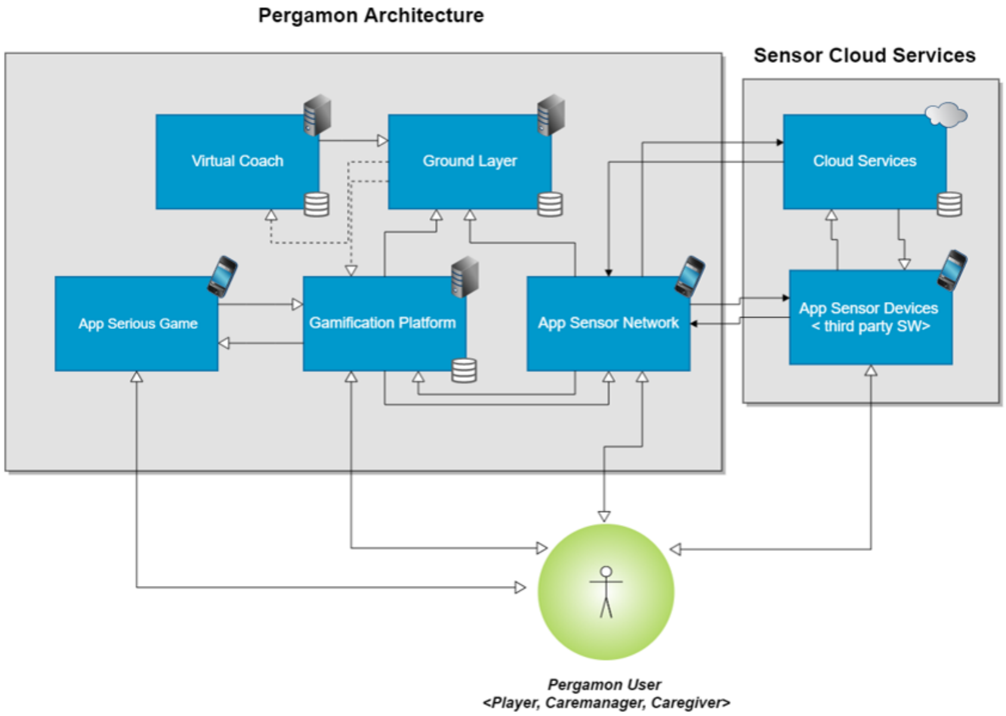

Figure 2. The PERGAMON architecture

useful? Do users find it difficult to use the system? Did users encounter any technical problems they could not solve?

Recruitment and session

Adolescents and their parents were contacted by the hospital and informed about the details of the study. Participants who were interested and met the inclusion/exclusion criteria (i.e. (a) having a diagnosis of type 1 diabetes for at least six months, (b) between 12 and 18 years of age, (c) written informed consent provided by adolescents and one of their parents/legal guardians, (d) availability of an Android smartphone with an internet/data connection (e) a reasonable understanding of the Dutch language) received an information letter and informed consent forms. Adolescents and at least one parent were then scheduled to attend a pre-test visit at the hospital.

At the pre-tet visit, after a parent provided his/her informed consent for their child, participants filled out 1) a socio-demographic questionnaire which included questions about their smartphone use and 2) a Dutch translation of the Problem Areas in Diabetes Questionnaire (PAID [33]) to assess diabetes related emotional distress. Participants were given a MiFi wrist band pedometer (and a mobile phone if they did not have one that satisfied the system requirements). Researchers assisted participants in downloading and installing the PERGAMON platform and associated apps. Participants were then able to take their equipment home for a period of 6-8 weeks when they had access to the platform. They were not given specific instructions regarding what to do except to use the platform and report about their experiences later. They were told to “just play the game and have fun” and that technical assistance was available for them from the care team or researchers via telephone or e-mail.

At post-test, user experiences were evaluated with 1) a semi-structured interview at the hospital and 2) a Dutch translation of the System Usability Scale (SUS; [4]). After completing these assessments, the adolescents participated in a focus group to elicit their suggestions for improving system performance and adequacy.

OUTCOMES

Fourteen patients (age 12-18) took part in the study. One participant indicated they used their smartphone to monitor and/or improve physical activity and another participant reported using their smartphone to monitor and/or improve nutrition. However, none of the participants reported having used their smartphone for BGM. Scores of the Problem Areas in Diabetes Questionnaire [33] indicated that participants did not experience a great deal of diabetes related emotional distress.

When asked about their use of the platform, 50 percent of the adolescents indicated that they played a couple of times a week and the other half said they played (almost) every day. The average playtime was 8 hours (over 6 to 8 weeks period) and ranged between 15 minutes and 40 hours.

When asked to give their general assessment of the platform, participants rated the game difficult to play and said that there

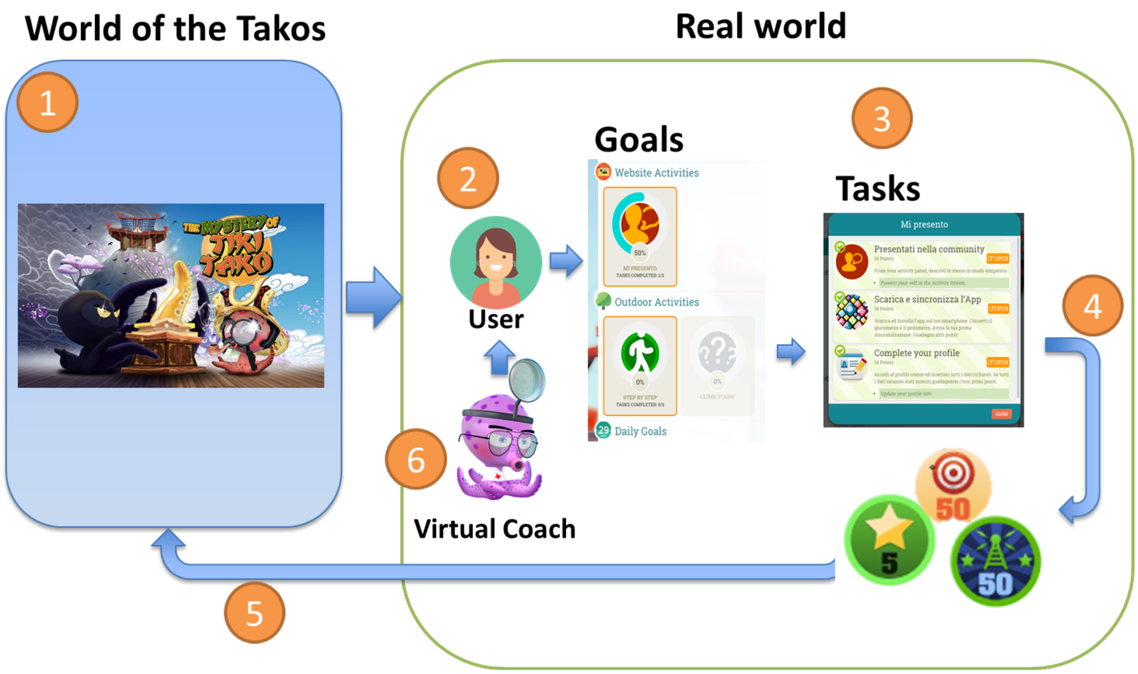

Figure 3. Main characteristics of the Tako Game for diabetic children (see Table 1 for explanation)

was not enough explanations given or that the explanations were difficult to understand. One participant indicated that they did learn from the game, specifically that it "refreshed" their diabetes knowledge. Almost all participants said they would like to get access to this game once the development was complete and that they would recommend the game to other adolescents with T1D. One said, " Because *you can learn diabetes knowledge and become more conscious about your condition*." Four participants reported that they discussed the game with family members and/or friends but only one participant indicated a desire to play this game with others.

Participants suggested that the mini-game could be improved by offering more explanations for certain mini-games or by offering the ability to adjust their difficulty levels. All participants (except for one) indicated that they received messages from the virtual coach (a range of 3 to 8 messages). Most messages concerned blood glucose measurements. One participant reported that the virtual coach's messages helped them with self-manage of their health behaviours. Participants suggested that the virtual coach could be improved if users could ask it questions and they thought it should appear less often on their phone screen as an overlay. Perhaps, related, compliments given by the virtual coach, for example in weekly overview messages, were not noticed by all users. Similarly, notifications sent by the virtual coach were reported as not being consistently given reflecting that if patients did not enter data after each measurement or at least once a day, the feedback by the virtual coach was not up-to-date or consistent.

Users suggested that it would be good if the coach could react to too high or too low GB values by sending a message. One participant said that their mother was the best coach he had. *"She never gives up to tell me that I have to measure, until I finally do, which is good."* All patients agreed that it would be good to have a virtual coach that could not be turned of that notified them when it was time for a BGM.

Not all users were enthusiastic about wearing a Mi-Fit band or to change their trusted blood glucose meter for a new meter that automatically sends glucose data to the platform (most participants used a pump and other glucose monitors). Entering the glucose measurements by hand was perceived as a lot of extra work.

Half of the participants indicated that they found the PERGAMON platform easy to use (statement 3 of the SUS test in Table 2) but they did not think that the various functions were well integrated in the system (statement 5). At the same time, most participants did not think they would need assistance to use the system (statement 4).

In addition to the user evaluations in the Netherlands, children in Italy from two age groups also play tested the mini games over a period of three days. The results showed that the younger group (n=12, ages 6-11) was more positive about the mini games than the older age group (n=10, ages 12-18). The younger age group indicated that it was useful to learn more about their diabetes through gaming in a fun and entertaining way. However, the older age group felt that the mini games (especially the graphics) were more likely to attract younger children. They also expected that younger children with T1D would find more educational benefit from the games as they might not yet know how to balance their blood glucose and how to inject insulin.

1	Theme: in the world of the Takos, an evil monk has stolen the sacred tentacle from the Temple. T-Shan is called in by the Great Red Tako to retrieve it. In order to accomplish his mission, T-Shan must overcome a series of challenges, helped by the player (the patient), who can guide T-Shan and obtain precious suggestions and points in the real world.
2	In order to gain points needed to help T-Shan in the world of the Takos, the player must accomplish the empowerment goals set in his/her game dashboard. These goals refer to: • Monitoring blood glucose level (entry in the diary, use of sensor device such as glucometer) • Acquiring skills and knowledge (learn carbohydrate counting, how to balance a healthy meal etc.) • Social activities (set up his/her personal profile, use the wall) Some goals are also directly linked to the game itself e.g. require the player to play a mini-game to be able to proceed to another scene in the temple. Players are never alone in their quest: they are helped by the Great Red Tako (i.e. the virtual coach), who supports and motivates them in accomplishing the set goals.
3	Each therapeutic goal is made up of several tasks. Some can be carried out directly online (e.g. take an "educational candy", i.e. view a learning resource, watch a video, read a document; or "fill in the diary"); others may be carried out unconsciously by the user in their daily activities, but thanks to the wearable sensor devices (glucometer and pedometer) that automatically detect and synchronise data about blood glucose level and physical activity, the PERGAMON system knows that a task has been carried out. Each completed task is rewarded by points.
4	Points are of three types, each type is linked to a specific type of action: • Experience: gained through the game; they contribute to the player's ranking in the general leaderboard • Knowledge: used in the world of Tako to unlock some locations • Evolution: used to let the Tako avatar grow and acquire graphical assets
5	Points are used to get suggestions (and thus solve a riddle or overcome an obstacle), or get an object that can be used later on to do something in the game in the world of the Takos.
6	The virtual coach in turn, situated in the real world, can affect the world of the Takos by - providing suggestions on some tasks particularly helpful for the users, that can make them gain points - advising to complete a goal related to the levels in the game

Table 1. Main characteristics and game elements of the Tako Game for diabetic children (see Figure 3)

CONCLUSIONS AND CHALLENGES AHEAD

Because of the central server architecture, progress in the game and coaching critically depended on the user being connected. What became clear from the evaluation in the wild is that we incorrectly assumed that users would be continuously online, they would wear their physical activity wrist band all day and they would consistently send their BG data to the sensor network immediately after measuring. Some carried their own mobile phone (not the phone provided) and used the phone provided for gaming only at home. This led to a less than optimal user experience. Despite these problems, the PERGAMON platform represents a proof of concept of a system that allows the integration of serious gaming and digital coaching to support patients with chronic conditions. The user trial studies show the importance of finding a good balance between flawless and non-obtrusive technology, between challenging but not too difficult game play, and the relevance of designing and fine-tuning to the age group as well as to the level of knowledge and experience of the individual user. Furthermore, the use of mobile technology in combination with web-based elements has shown to be feasible with potential to change health care by supporting a vulnerable group of patients in self-managing their chronic disease. Further research on these types of platforms with larger groups of patients (including those recently diagnosed) in a hospital setting over a longer period are needed to see if indeed gamification helps patients to automate self-care behaviours and to see what features and game elements contribute to a positive user experience and increase self care for patients with a chronic condition.

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		Disagree (1-2)	Neutral (3)	Agree (4-5)
Positive items				
1)	I think that I would like to use this system frequently	57.1	21.4	21.4
3)	I thought the system was easy to use	28.6	21.4	50.0
5)	I found the various functions in this system were well integrated	50.0	35.7	14.3
7)	I would imagine that most people would learn to use this system very quickly	57.1	14.3	28.6
9)	I felt very confident using the system	42.9	35.7	21.4
Negative items				
2)	I found the system unnecessarily complex	35.7	28.6	35.7
4)	I think that I would need assistance to be able to use this system	57.1	28.6	14.3
6)	I thought there was too much inconsistency in this system	50.0	28.6	21.4
8)	I found this system very cumbersome/awkward to use	42.9	35.7	21.4
10)	I needed to learn a lot of things before I could get going with this system	50.0	28.6	21.4

Table 2. SUS questionnaire for PERGAMON platform (in %)

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