SmartLife

Smart Clothing Gamification to promote Energy-related Behaviours among Adolescents

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***Abstract*—Inactivity and high sedentary behavior among adolescents are main societal problems. Unhealthy lifestyles place a large burden on society and promoting healthy lifestyles is thus key for health, wellness and economic prosperity. These non-communicable diseases and unhealthy lifestyles furthermore occur more often among lower socio-economic groups, which indicates a need for healthy lifestyle promotion programs to help reduce health inequalities and improve social inclusion. The *SmartLife* project aims to create a mobile game that requires lower body movement, and is personalized by physiological feedback measured by smart textiles. Personalization via smart textiles can present a game challenge achievable for the current fitness level of the player and can adjust this based on activity levels during game play. This approach can improve current exergames to achieve a higher level of intensity in physical activity, needed to create a health impact, and can do so considering what is achievable for the person and hence reduce drop-out and injury risks.**

Keywords—e-health; exergames; smart textiles; data analytics

I. Introduction

There is a high prevalence across Europe of non-communicable diseases such as cardiovascular diseases, diabetes type II, certain types of cancer and depression, and this prevalence continues to rise. These diseases account for a large proportion of morbidity and mortality causes, and bring about related health care costs and reduced productivity. The main cause of these diseases is the occurrence of unhealthy lifestyles [1]. Unhealthy lifestyles place a large burden on society and promoting healthy lifestyles is thus key for health, wellness and economic prosperity. These non-communicable diseases and unhealthy lifestyles furthermore occur more often among lower socio-economic groups [2], which indicates a need for healthy lifestyle promotion programs to help reduce health inequalities and improve social inclusion.

Many unhealthy lifestyles track from childhood and adolescence track into adulthood and early interventions to promote healthy lifestyles among youth can thus contribute to reduced morbidity and mortality in adulthood. Especially in the transition phase from elementary school to secondary school, there is a risk that unhealthy lifestyles such as lack of physical activity and high sedentary behavior predominate [3]. The most common unhealthy lifestyles among adolescents are low physical activity (62% of adolescents), and high sedentary behavior (45% of adolescents) [4]. These are forms of energy-related behaviors which, combined with a healthy diet, create an energy balance and thus reduce the risk of overweight or obesity. These data demonstrate that much improvement can be made in adolescents' health by improving the energy-related behaviors of physical activity, fitness and reducing sedentary behaviors. Since there is a socioeconomic gradient in these behaviors among adolescents, an intervention to optimize these healthy lifestyles will especially benefit the health of adolescents of lower socio-economic status. Another at-risk group that showed significantly lower physical activity and more sedentary behaviors were adolescent girls [5]. These two at-risk groups deserve specific attention when designing programs to promote energy-behaviors.

One type of lifestyle intervention that may increase physical activity, physical fitness and reduce sedentary behavior are exergames, also known as active video games. These are games using digital media, requiring body movement to be played and where the game outcome is mainly determined by the player's physical efforts. Games may have a great potential to address energy-related behaviors among adolescents. Firstly, adolescents prefer exergames to traditional exercises [6]. Secondly, since enjoyment of performing the activity is a main determinant of physical activity, the fun and intrinsically motivating aspect of games can increase the chance that adolescents will perform the physical activity. Thirdly, youngsters perceived the exertion levels in exergames as lower than what they did in reality, also showing they felt less exhausted and may be able to continue for longer [7]. A game may thus lead to a higher preference and enjoyment of the intervention, a higher compliance (i.e. chance that the target user will perform the exercise), and a longer sustained activity behavior.

In conjunction with exergames as a way to promote physical activities within the youngsters, smart wearables can also be a valid method for measuring physical activity [8]. Smart textiles offer several advantages to other types of smart wearables worn on the wrist or as a clip-on that are commercially available: 1) smart textiles do not deduce physical activity from arm movements, which is important when lower-body movements are targeted to create an intensity of sufficient level; 2) by measuring not only heartrate, steps and acceleration, but also respiration, they can distinguish between moderate and vigorous levels of physical activity and allow for a more granular type of personalization, to also improve health-related fitness. Smart textiles yield a richness of real-time information that can be broken down via big data analytical methods to discover new patterns that can be used as a basis for tailoring.

In sum, the overall aim of the *SmartLife* project [9] is to create a mobile serious game that requires lower body movement, and is personalized by physiological feedback measured by smart textiles. To date, no serious games exist that personalize the game play by real-time feedback on achievement of the target behavior. Personalization via smart textiles can present a game challenge achievable for the current fitness level of the player and can adjust this based on activity levels during game play. This approach can improve current exergames to achieve a higher level of intensity in physical activity, needed to create a health impact, and can do so taking into account what is achievable for the person and hence reduce drop-out and injury risks. It is intended to provide European adolescents with an individually tailored, evidence-based and engaging gamification tool to promote physical activity, fitness and reduce sedentary behavior by using feedback from smart textiles, and thus contribute to the prevention of non-communicable diseases and conditions related to unhealthy lifestyles, such as overweight and obesity, diabetes type II and common mental disorders.

This paper is structured as follows: Section 2, describes the relevant literature on exergaming and its relation to physical activity; Section 3, describes the technical conceptual approach to be addressed within *SmartLife*; The *SmartLife* game development process, will be described in section 4; Section 5 describes the data sources that will be collected through smart textile and also the protocol used from collecting physical activity data from users; Finally, section 6 concludes the paper.

II. Related Work

Current exergames aiming to promote energy-related behaviors have resulted in a too low level of energy expenditure to impact health, and were often not sufficiently motivating to be continued to play. *SmartLife* aims to deliver an engaging exergame that can reach recommendations for moderate-to-vigorous physical activity and sedentary behavior, but adopting a tailored approach in an exergame requiring lower body movements, with additional immersive features such as a narrative and contextual information.

Current exergames have proven to result in too little energy expenditure to be considered as having health benefits [6]. At most, they promote light physical activity, or reduce sedentary behavior on the condition that the game cannot be played by mere wrist flicks. Exergames requiring lower body movement have been more successful at reaching higher energy expenditure [6], and some results may depend on the individual user. Although exergames are preferred by youngsters in comparison to regular exercises [6], their appeal in comparison to other digital games is limited [10]. Active video games have less appeal because they offer fewer options and worse controls [11]. They are on average played for less time per week than non-active digital games (respectively on 1.5 days versus 3.3 days per week) [12]. This illustrates that not only the potential for effectiveness of exergames to impact energy-related behaviors, but also their motivational appeal among adolescents leaves room for improvement. One aspect that was associated with higher exergaming enjoyment and the intention for continued use, was the degree to which the game met the basic psychological needs of competence, autonomy and relatedness [13]. In-game performance in its turn was associated with a higher degree to which these basic psychological needs were met. This indicates that when players feel better at meeting the challenge, this has a positive impact on enjoyment and intention for continued use, and suggests that the challenge may be best attuned to what is feasible for the player to experience success. *SmartLife* design will therefore take these principles into account in the design, by using a tailored approach better attuned to players' needs and abilities, and by applying the Self-Determination Theory in game design. Self-determination theory addresses motivational aspects of behavior. It states that in order to be motivated, three basic psychological needs should be met, namely perceived autonomy, competence and relatedness. This framework has previously been applied to serious game development [14] and showed greater behavior change when feelings of autonomy and competence were met. Little research is available on relatedness in game development. The *Smartlife* project aims to design the game in such a way to maximize autonomy (e.g. high user control and interactivity), competence (e.g. by tailoring to what is feasible based on their current activity behavior) and relatedness (e.g. including a social function via social networking or communities). Another aspect which may also improve the motivational and engaging appeal of exergames is the inclusion of narratives. Narratives could enhance a sense of presence in the game, but care should be taken that is does not limit the autonomy and level of choice in the game. Current use of narratives in exergames is scarce [15]. And finally, physical activity and sedentary behavior is also influenced by environmental factors. So far, little context information has been used in exergames [16].

To our knowledge, no existing exergame has tailored the physical activity challenge to the extent to which players are performing physically and to their level of fitness. This can create a higher sense of basic psychological need satisfaction, e.g. by feeling more competent, and can advance the way exergames, and in extension all digital health games, are created. More real-time monitoring of the behavior could enhance the effectiveness of tailoring in games, rather than basing tailoring on information only collected prior to game play, or collected at large intermediate intervals. Evidence is currently lacking on this topic, and this is a highly innovative aspect of this project. Furthermore, the smart textiles enable to distinguish between types of physical activity and measure sedentary behavior. By adjusting activities based on a detailed level of their energy expenditure in the game, the games are more likely to reach the recommended levels of physical activity and sedentary behavior for adolescents.

Current motivational appeal of exergames is limited, despite a large potential to get youngsters to be more active and expend more energy. The approaches suggested here to add to the motivational appeal of exergames are novel, such as narratives and location-based info, and to our knowledge have not been experimentally tested for their effects. Integrating location-based gaming aspects, by using GPS information on the smartphone, extends the possibilities to create an engaging game, that can also address environmental determinants of energy-related behaviors. Land mix use and urban design indeed influence energy-related behaviors. In order to destigmatize health problems related to physical inactivity, it is important to also acknowledge these environmental contributors to low energy-related behaviors. Integrating this in a game can enhance game immersion by having a closer matching of the real-life world, i.e. the physical location where the game is played, and the game world, i.e. the narrative, which causes a richer experience. The player may also become more aware of the physical environment and of taking routes that can facilitate physical activity, such as road safety, street connectivity, or attractiveness of the locations. This is a novel and innovative area, both in terms of individual-based interventions addressing environmental determinants and of exergames using real-time location-based information.

The SmartLife project aims to expand on current state-of-the-art by designing an exergame yielding sufficient energy expenditure to enable adolescents to meet health recommendations, that is tailored by real-time energy-expenditure information, and that is engaging by exploring the possibilities of including a narrative or geographical context-information.

III. Conceptual Approach

The project combines approaches from technical, social and health disciplines. All efforts will be trans-disciplinary. Many models have a common ground but with a different focus in several disciplines. For example, there are many similarities between gaming methods and behavioral change methods, albeit often with a different purpose (behavior change, engagement and enjoyment). Self-Determination Theory as a basic model in product development is shared by both disciplines. Individual tailoring can be fed from data analytics on patterns emerging from the data (data-driven approach), or can be fed by what is desired and feasible to reach (outcome-driven approach). These approaches will be combined here, and the partners will work transdisciplinary on achieving this.

The *SmartLife* intervention design is based on four specific concepts and approaches: a) a holistic approach, meaning that we focus on different lifestyle factors to promote adolescent health and social inclusion; b) the concept of tailored personalized support based on theoretical considerations, behavioral evidence, real-time assessments and dynamic mathematical models; c) coupling of effectiveness and motivation for continued product use, based on evidence-based methods, behavior change theories, and gamification elements; d) a participatory approach involving end-users in the project to ensure adoption of the final product.

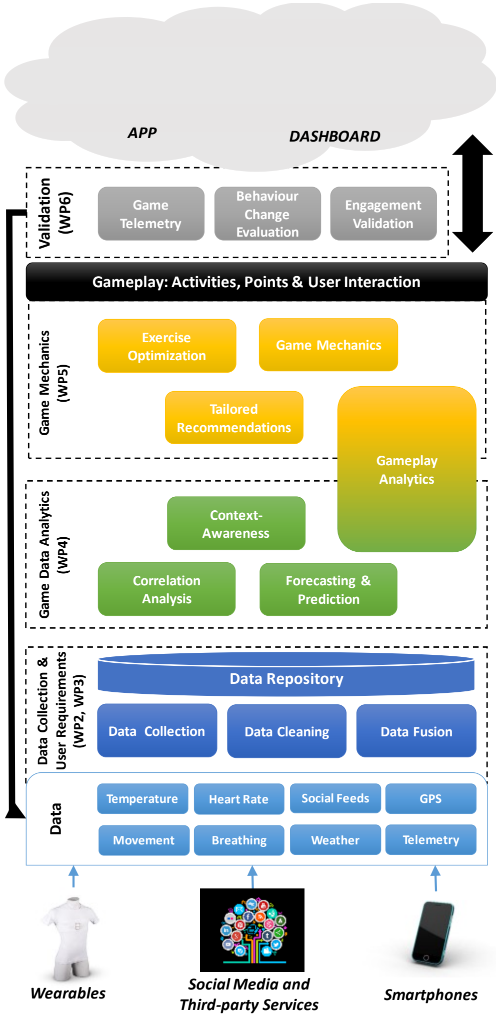

Fig. 1. SmartLife Conceptual approach

For this purpose, *SmartLife* is wrapped around the following very clear main objectives:

- to integrate key elements of serious game systems with smart-textile information systems and allow for data-exchange between these systems;
- to develop and evaluate in-game exercises that can promote physical activity of sufficient intensity (moderate-to-vigorous) and require lower body movements;
- to develop a mathematic dynamic model predicting the dynamics between key information from smart textiles and in-game behavior;
- to develop a tailored intervention to promote physical activity, fitness and reduce sedentary behavior, based on users' needs and preferences in a gaming and smart wearable context;
- to develop and evaluate a serious game to promote energy-related behaviors for adolescents with integrated smart textiles tailored feedback, based on users' needs and preferences;

- to develop a business model, based on an analysis of the business ecosystem;
- to develop a dissemination plan and migration path to support further validation, dissemination, acceptance and use of the *SmartLife* mobile gaming and smart textile system among European adolescents.

IV. SmartLife Gaming Analytics Process

In this section, we will introduce the gaming analytics process to be followed by *SmartLife*. The different types of data collected and generated during gameplay, can form the input to the game analytics process. Several useful gameplay metrics can be considered such as: session length, calories burned, exercises chosen, match between exercises shown and player actions, player accuracy in performing exercises, total playtime over X days, player hardware/exercise equipment [usually registered], player demographics [usually entered during pro fi le creation], music tracks selected, backgrounds selected, avatar selection, powerups/content unlocked [common feature], total duration of play per user.

Game analytics is the application of analytics to game development and research. The goal of game analytics is to support decision making, at operational, tactical and strategic levels and within all levels of an organization – design, art, programming, marketing, user research, etc. Game analytics forms a key source of business intelligence in game development, and considers both games as products, and the business of developing and maintaining these products [17].

The game analytics process to be addressed within *SmartLife* project, follows the standard process for knowledge discovery in data [18], which is widely used in data-driven analytics to discover useful knowledge from data. Knowledge discovery can be described in a number of phases or steps, which are fundamentally cyclic in nature, i.e. the result of an analysis cycle can feed into the next cycle. This is one way of continually optimizing the discovery process. Fig. 2, presents a brief overview, with phases adapted to the context of game development and the focus on user telemetry as the data source.

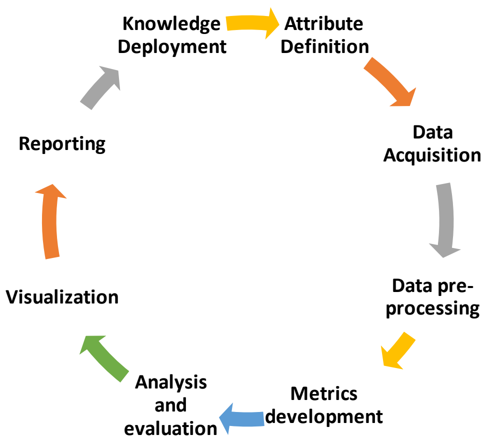

Fig. 2. The knowledge discovery process adapted to the context of the SmartLife game analytics

Attribute definition: The first step in the process is defining the objectives, and the requirements, the result of the discovery process must fulfill. During this phase the user attributes to track are selected, as well as the tracking strategy (event, frequency or initiated). Domains for each attribute are de fined, and goals for each domain defined. For example, it may be a goal that the maximum playtime for a game in total is set to 20 h (i.e. the game should not take any longer to complete). During this phase, strategies for balancing pre-defined metrics and results are balanced against the requirement for being able to explore and drill-down/ across/through datasets.

Data acquisition: Once the attribute set has been defined, it is implemented in the telemetry system the company uses. If no such system exists, one will have to be either purchased or a service agreement entered. There are fundamentally three ways to obtain a telemetry system: (1) develop in-house, (2) purchase a license, or (3) purchase access to a software-as-service solution. There are at the time of writing about two-dozen companies worldwide offering telemetry solutions for games. Several of these are solutions developed for e.g. business analytics or web analytics, but are also applicable to some, and in a few cases all, types of games. There are unfortunately no comprehensive guides or reviews of telemetry providers currently available, and a degree of research is therefore needed to locate the solution best suits the requirements.

Data pre-processing: During this step, incoming telemetry data are transformed and loaded into a database structure, from where they are accessible for analysis. Additionally, data are cleaned and otherwise made ready for analysis.

Metrics development: following pre-processing, the attribute data are transformed into variables/features and metrics. This can be done automatically (e.g. KPIs) or manually.

Analysis and evaluation: During this step, cases and features are selected as required by the analysis in question. Sampling can also be applied to minimize resource requirements. The chosen analysis is run and a model generated of the results. Furthermore, results are evaluated and it is checked if the model reaches the required objectives.

Visualization: The results are visualized in a way that is functional given the stakeholders they are aimed at, following principals of knowledge visualization.

Reporting: The discovered knowledge is presented to the relevant stakeholders, e.g. a designer. The reporting/presentation should be done in such a way that the stakeholders can understand, interpret and act on the result.

Knowledge deployment: The knowledge is deployed in the organization. This will often see the initiation of a new discovery cycle.

V. Data Collection

The objective of this chapter is to provide an understanding on what types of data the system expects to collect, and also in what format the data is transferred. There are various sources from where meaningful data can be extracted to be analyzed and used. The main two, are data collected from the wearable textile and data collected from the smartphone.

A. Data Types Collected from Smart Textile

D Regarding data collected from the smart textile, there are some types that can be useful to provide a good insight on the intensity levels of users' exercise.

Heart rate (the number of times your heart beats per minute), is important because a healthy heart rate will improve sleep quality, stress levels and caloric burn. Typically measured in beats per minute (bpm), heart rate will vary between individuals according to their physicality.

Breathing rate (also called respiratory rate) is the rate at which breaths occur, usually measured in breaths per minute. It can be measured with respiratory monitors, devices that record the user's pulmonary ventilation.

Movement (Traveling from one point to another). Moving is important because it uses energy, even if it's just walking around. It burns calories, it boosts energy and morale, it improves sleep quality and it prevents disease. It can be measured by pedometers, but in terms of general movement tracking, this measure must be combined with other metrics such as heart rate or calories burned.

Calories burned in definition is the amount of energy required to raise the temperature of 1 gram of water by a single degree Celsius. The importance of calories is that everything the body does (move, think, eat, breath) every muscle needs to burn calories. According to WIRED [19] to measure the number of calories burned an indirect calorimeter device is needed. These devices are the best way to track calorie burn since breathing has a direct relation to the amount of energy expended. The problem of the indirect calorimeters is the $30000 to $50000 price since those most commonly come in the form of a 5-pound backpack-sized contraption that analyses oxygen consumption using a face mask or mouthpiece. To overcome these costly devices, today's wearables can estimate calories burned with accurate to around 10 percent by using proprietary algorithms that factor in the wearer's age, height, weight and gender.

Skin temperature depends on air temperature and time spent in that environment**.** The skin is the largest organ in the human body and it protects it from external factors. As mentioned previously, the sweat glands are the skin's primary defence against overheating. The glands release moisture and cool down our bodies' core temperatures. Exercise causes skin temperatures to rise. Because body temperature represents the balance between heat production and heat loss [20] monitoring skin temperature is important to avoid body overheating or hypothermia. The ability to measure skin temperature is rare in the world of wearable devices. The ones that can, have thermometer sensors to measure temperature.

All these metrics can be extracted via Bluetooth from the wearable device directly to the smartphone. Bluetooth has been selected as communications technology between the smart textile and the smartphone due to the reliable performance regarding power requirement, data rate, and latency. It is also a technology that is widely used by smartphones and several kinds of wearable devices.

B. Data Types Collected from Smartphone

A With the amount of sensors and processing capability of smart devices, the variety of the passive data (volunteered information) that can be extracted is vast.

GPS location (a satellite's approximation of a person's current location) is important not only to help navigation but also to more accurately track distances, elevations, and energy consumption. With GPS, is possible to gauge speed, distance and location. These metrics help determine to amount of calories burned and the overall success of a workout. Still an estimate, the GPS in present in the smartphone is capable of tracking the wearer's path throughout the day.

Accelerometer is one of the most common inertial sensors being a dynamic sensor capable of a vast range of sensing. They measure acceleration in one, two, or three orthogonal axes, operating as an inertial measurement of velocity and position or as a vibration or impact (shock) sensor.

Gyroscope adds an additional dimension to the information supplied by the accelerometer by tracking rotation or twist. This is done by sensing angular velocity (angular rate) along one rotational axis.

Data collected from both accelerometer and Gyroscope can be useful to detect and analyse user movement. Other types of data that don't come from sensors in the smartphone but can be collected by the smartphone is for example meteorological information. This can be important not only to inform the user that is doing an outdoor activity that the weather may change but also to suggest an outdoor activity if the weather is allow it.

C. Data Formats

This section provides an overview of the communication and data formats exchanged between smart t-shirt and android smartphone, supported by Bluetooth protocol. Bluetooth 5 delivers a "connectionless" IoT, advancing beacon and location-based capabilities in home, enterprise and industrial applications. Bluetooth Low Energy (BLE) is based on two protocols: ATT (Attribute Protocol) and GATT (Generic Attribute Profile). They specify the communication layers used by every Bluetooth Smart Ready device. Fig. 3, depicts a conceptual approach for integrating and collecting data through smart textile to *SmartLife* APP via Bluetooth protocol.

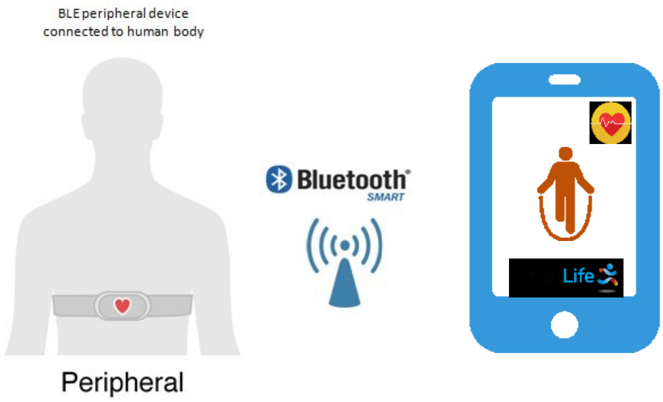

Fig. 3. Communication between smart t-shirt and SmartLife APP

GATT (Fig.4) is an acronym for the Generic Attribute Profile [21], and it defines the way that two Bluetooth Low Energy devices transfer data back and forth using concepts called Services and Characteristics. It makes use of a generic data protocol Attribute Protocol (ATT), which is used to store Services, Characteristics and related data in a simple lookup table using 16-bit IDs for each entry in the table.

An important concept to understand with GATT is the server/client relationship. The peripheral is known as the GATT Server, which holds the ATT lookup data and service and characteristic definitions, and the GATT Client (the phone/tablet), which sends requests to this server. All transactions are started by the master device, the GATT Client, which receives response from the slave device, the GATT Server. GATT transactions in BLE are based on high-level, nested objects called Profiles, Services and Characteristics, which can be seen in Fig. 4:

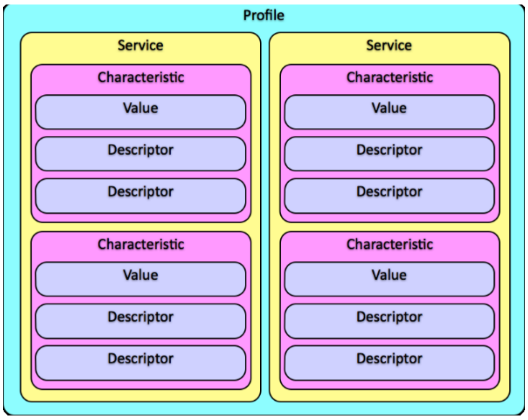

Fig. 4. The Generic Attribute Profile (GATT)

A **Profile** does not actually exist on the BLE peripheral itself, it is simply a pre-defined collection of Services that has been compiled by either the Bluetooth SIG or by the peripheral designers. The Heart Rate Profile, for example, combines the Heart Rate Service and the Device Information Service. The complete list of officially adopted GATT-based profiles can be seen here: Profiles Overview.

Services are used to break data up into logic entities, and contain specific chunks of data called characteristics. A service can have one or more characteristics, and each service distinguishes itself from other services by means of a unique numeric ID called a UUID, which can be either 16-bit (for officially adopted BLE Services) or 128-bit (for custom services). A full list of officially adopted BLE services can be seen on the Services page of the Bluetooth Developer Portal. If you look at the Heart Rate Service, for example, we can see that this officially adopted service has a 16-bit UUID of 0x180D, and contains up to 3 characteristic, though only the first one is mandatory: Heart Rate Measurement, Body Sensor Location and Heart Rate Control Point.

The lowest level concept in GATT transactions is the **Characteristic**, which encapsulates a single data point (though it may contain an array of related data, such as X/Y/Z values from a 3-axis accelerometer, etc.). Similarly to Services, each Characteristic distinguishes itself via a pre-defined 16-bit or 128-bit UUID, and it is free to use the standard characteristics defined by the Bluetooth SIG (which ensures interoperability across and BLE-enabled HW/SW) or define own customizable characteristics which only the peripheral and SW understands. As an example, the Heart Rate Measurement characteristic is mandatory for the Heart Rate Service, and uses a UUID of 0x2A37. It starts with a single 8-bit value describing the HRM data format (whether the data is UINT8 or UINT16, etc.), and then goes on to include the heart rate measurement data that matches this config byte. Characteristics are the main point that will interact with the BLE peripheral, so it's important to understand the concept. They are also used to send data back to the BLE peripheral, since it is also able to write to characteristic.

GATT specifies that the above used UUID 0x2800 marks the begin of a service definition. Every attribute following 0x2800 is part of the service until the next 0x2800 or the end is encountered. In similar ways the well-known UUID 0x2803 states that a characteristic is to be found and each of the characteristics has a type defining the nature of the value. The example above uses the UUIDs 0x2A08 (Date Time) and 0x2A37 (Heart Rate Measurement). Each of the above UUIDs is defined by the Bluetooth Special Interest Group. and can be found in the GATT specification. While it is advisable to use pre-defined UUIDs where available it is entirely possible to use new and not yet used UUIDs for characteristic and service types. In general, each service may consist of one or more characteristics. A characteristic contains data and can be further described by descriptors, which provide additional information or means of manipulating the characteristic. All services, characteristics and descriptors are recognized by their 128-bit UUID. Finally, it is possible to include services inside of services (see table 1).

TABLE I. EXAMPLE OF CHARACTERISTICS FOR THE HEART RATE SERVICE

Handle	UUID	Value	Description
0x0001	0x2800	UUID 0x180D	Begin Heart Rate service
0x0002	0x2803	UUID 0x2A37, Value handle: 0x0003	Characteristic of type *Heart Rate Measurement (HRM)*
0x0003	0x2A37	65 bpm	Heart rate value
0x0004	0x2803	UUID 0x2A08, Value handle: 0x0006	Characteristic of type Date Time
0x0005	0x2A08	18/08/2014 11:00	Date and Time of the measurement
0x0006	0x2800	UUID xxxxxx	Begin next service
...	...	...	...

VI. CONCLUDING REMARKS

This paper presented a conceptual approach being addressed within *SmartLife* project, aiming at provide European adolescents with an individually tailored, evidence-based and engaging gamification tool to promote physical activity, fitness and reduce sedentary behavior by using feedback from smart textiles, and thus contribute to the prevention of non-communicable diseases and conditions related to unhealthy lifestyles, such as overweight and obesity, diabetes type II and common mental disorders.

Our initial findings indicate that, current exergames aiming to promote energy-related behaviors have resulted in a too low level of energy expenditure to impact health, and were often not sufficiently motivating to be continued to play. With *SmartLife* we aim at delivering an engaging exergame that can reach recommendations for moderate-to-vigorous physical activity and sedentary behavior, but adopting a tailored approach in an exergame requiring lower body movements, with additional immersive features such as a narrative and contextual information.

From a more technical and development perspective, *SmartLife* will use the knowledge discovery process adapted to the context of the game analytics. Historically, game development has not been data-driven, but within *SmartLife*, we will adopt and adapt analytics techniques to gain better knowledge about the users – the players.

ACKNOWLEDGMENTS

The authors acknowledge the European Commission for its support and partial funding and the partners of the research project: H2020– 732348 *SmartLife*.

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