PEGASO: A Personalised and

Motivational ICT System to Empower

Adolescents Towards Healthy Lifestyles

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Abstract. Unhealthy alimentary behaviours and physical inactivity habits are key risk factors for major non communicable diseases. Several researches demonstrate that juvenile obesity can lead to serious medical conditions, pathologies and have important psycho-social consequences. PEGASO is a multidisciplinary project aimed at promoting healthy lifestyles among teenagers through assistive technology. The core of this project is represented by the ICT system, which allows providing tailored interventions to the users through their smartphones in order to motivate them. The novelty of this approach consists of developing a Virtual Individual Model (VIM) for user characterization, which is based on physical, functional and behavioural parameters opportunely selected by experts. These parameters are digitised and updated thanks to the user monitoring through smartphone; data mining algorithms are applied for the detection of activity and nutrition habits and this information is used to provide personalised feedback. The user interface will be developed using gamified approaches and integrating serious games to effectively promote health literacy and facilitate behaviour change.

Keywords. Multi-Domain Virtual Individual Model, Risk Factors, Sensors Parameters, Data Mining, Serious Games and Gamification.

Introduction

The rapidly increasing prevalence of overweight and obesity among children and adolescents reflects a global 'epidemic' worldwide. Due to the associated serious medical conditions, it is estimated that obesity accounts for up to 7% of healthcare costs in the EU, as well as costs to the wider economy associated with lower productivity, lost output and premature death. Obesity in younger age groups has been recognised as an alarming key predictor for obesity in adulthood, but also entails a number of short term health complications such as hypertension, type 2 diabetes, metabolic syndrome, fatty liver disease, sleep disturbances along with greater risk of social and psychological problems.

Among the principal strategies tackling the risk of obesity in young individuals, a great relevance should be given to personalised actions enhancing motivation, behavioural skills and awareness for appropriate diet and physical activity. The PEGASO project aims at developing a multidimensional and cross-disciplinary ICT system fostering healthy behaviour among adolescents. "Behaviour" is defined as the way in which one acts or conducts oneself, especially towards others[2]. In this specific work, "user behaviour" is represented as an act that a teenager performs that can be observed, measured, and is repeated over time. PEGASO models the user behaviour to be able to operationally define the *target behaviour* (i.e. the behaviour to be changed or the problem to be faced) as well as the *desired behaviour* [1].

The paper is structured as follows. Section 1 introduces the proposed user model for designing personalised motivation mechanisms. Section 2 presents the different typologies of information used by the reasoning system presented in Section 3 for user behaviour recognition. Section 4 illustrates design principles for the generation of motivational mechanisms based on the information processed as explained in the previous sections. Finally, Section 5 presents a summary of the PEGASO approach and key features of the system.

1. User Modelling for System Personalisation

The PEGASO strategy relies upon the empowerment of the adolescents' everyday life habits, in their specific socio-cultural context, using an interactive-persuasive approach. To this aim, the system is designed around the definition of a Virtual Individual Model (VIM) stemming from a conceptual framework of basic relations between the individual's physical, psycho-social and behavioural aspects, which are considered to concur dynamically to health, as summarised in the scheme below (Figure 1).
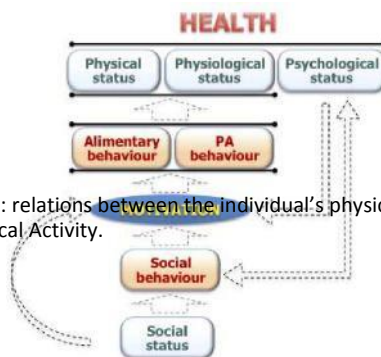

Figure 1. Base of the VIM model: relations between the individual's physical, functional and behavioural aspects. PA – Physical Activity.

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[2] http://www.oxforddictionaries.com/definition/english/behaviour

According to this scheme, body structure and functionality are directly influenced by the individual's behaviours in the domains of alimentation and Physical Activity (PA), which in turn depends on relevant aspects of motivation. Psychosocial factors are assumed to play an important role on individual's motivation for alimentary and physical activity habits. In such a context, status and behaviours in the different domains are defined by appropriate profiling including parameters which are relevant for quantitative characterization and detection of changes.

1.1. Personalised intervention and user profiling

Teenagers have very different cultures, motivations and needs. Using a standard model to describe this category would be too generic and, eventually, inaccurate. The advantage of the VIM and the subsequent profiling step is the possibility to specialise, tailor the model to a specific user and his/her specific needs [2]. Research has shown that computer-tailored health education could be an important approach that can be used to promote physical activity [3] as well as motivating people to make dietary changes [4]. However, in order to provide a personalised intervention, it is important to identify and model the user characteristics, needs and goals. A multifaceted profile is therefore needed to characterise the user, thereby generating an ecologically valid and complex model such as the VIM being proposed in PEGASO:

- *Physical activity and alimentary behaviours* – The concomitant role of physical activity and diet during adolescence for the prevention of overweight and obesity has been thoroughly recognised [5] and the engagement in healthy behaviours has been highly recommended [6]. Therefore, the habits concerning sedentary activities and consumption of energy-dense food/snacks and beverages are crucial for individual's profiling and assessment of health risks.
- *Psycho-social characteristics* – Understanding the various psycho-social influences which may impact on adolescent dietary behaviour and physical activity is important and through targeted and tailored motivational feedback, users will be guided towards healthier behaviour (e.g. going out with friends to do some sports activities, choosing healthy options at school lunchtime)
- *Gamers profile* – The PEGASO system will use serious games as an interactive communication tool through which to engage users. However, previous research has demonstrated that a user will only play a game if it provides some form of fun and that different people enjoy different types of fun (e.g., Bartle's model of players' types [7] and its evolutions [8]). Therefore, the profiling of the user as a gamer is crucial for the adoption of the feedback that is provided through the PEGASO system.

2. Sources of information

Several user focus groups and four main pilots will take place in Italy, Spain and United Kingdom (Scotland and England). These pilots will facilitate user information acquisition and at the same time validate the PEGASO system. A large amount of

information will be processed during these studies. In order to have a rich, multi-domain and dynamic representation of the user, the VIM requires different kinds of information: risks factors (from the physical, functional, physiological, psycho-social representation of the user), context data, social data, demographic data and medical history. The system includes three main sources of information: a sensor platform, questionnaires and applications.

The PEGASO **sensing platform** (SP) will integrate three typologies of sensors: the smartphone, smart garments and external devices. Largely diffused among teenagers, modern smartphones have different kinds of sensors that can be very useful for the analysis of users' activities. Technological progress is turning the smartphone into a laptop that includes geolocation, personalised configuration, built-in sensors and a large number of applications such as image capture and transfer, speech processing or social networks. Among others embedded sensors, accelerometers and gyroscopes can be used as sensors of movement capable of detecting volume, intensity and modality of motor activity performed in the everyday life context. Wearable technology such as garments, bracelets or pendants can be enriched with embedded, invisible sensors. Specific garments have the advantage to have implicit access to measurements that cannot be achieved with the smartphone. Sensors in direct contact with the user skin can detect hearth rate, galvanic skin response (GSR) and other biomedical signals for physiological characterisation and permit measurements that would be difficult or highly disruptive to acquire with conventional laboratory approaches. In addition, with seamlessly embedded sensors, the system will limit the encumbrance improving the user experience. Finally, also external devices will be used to track the user health status. In particular the system will integrate a scale or a balance board. A balance board allows a frequent assessment of an individual's weight and body composition and can also be used for directly measurable physical activities, also in a gaming context. The scale will be able to transmit the information to the user's smartphone and through it towards PEGASO system. Differently from the garments and the smartphone that can acquire information in an almost invisible fashion, the teenagers will consciously use the external devices.

Designed by experts, **questionnaires** have the twofold goal of acquiring an initial profile of the user before the actual use of the system, and acquiring data that are difficult or problematic to sense with other automatic means.

Through the smartphone **applications**, the user will be able to interact directly with the PEGASO system. In particular, the main interaction possibilities will be: serious games, social media applications and an interactive multimedia diary. PEGASO applications will propose serious games and activities in order to foster a healthier life-style. Games will work both as motivators and channels to directly acquire information about the users and their status evolution. The smartphone will enable the user to store physical and nutritional variables encouraging self-monitoring and improving the goal acquisition. Several studies demonstrated the importance of the psychosocial factors for promoting behaviour changes [9]. The use of social media applications, which are popular among teenagers, can establish a certain social pressure to acquire a healthy nutritional behaviour. This takes into account nutritional counselling strategies that have evolved over the last decades and in particular the social cognitive behaviour [10,11]. *Social cognitive behaviour* is based on the idea that people learn also by observing others and in particular their social interactions

and experiences. Social media applications and games are not two disjoint sets and shared elements can be used to propose activities and games to the users. The third element for direct user interaction is the multimedia diary. A Multimedia Diary Platform is used for behaviour and surrounding environmental data monitoring. Diaries represent the user interfaces to collect data concerning psychological and nutritional behaviours.

3. Exploiting information: Data mining and reasoning approaches

In order to achieve a personalised set of motivational tools fully adapted to the requirements of each user, it will be constructed an algorithm infrastructure based on data mining techniques to allow inferring over the VIM with the objective of producing a Behaviour Recognition System (BRS). The BRS will interact with the motivational mechanisms presented in the Section 4. The individual behavioural habits and the related risk factors will be processed and sent to the cloud and, consequently, to the ecosystem of stakeholders and experts. BRS will build upon the information coming from questionnaires, the sensing platform, and the applications (as explained in the previous section). The recognition system will include applications for data analysis, data cleaning, mapping, manual and semi-automatic categorisation, and data comparison (e.g. data correlation). In addition, the BRS will provide dynamic multiscale modelling of user-specific data and constitute the software interface between the sensing platform and the user-interface.

This module is composed of two phases: small-timescale and long-timescale trend behaviour recognition.

3.1. Small-timescale trend behaviour recognition

Raw data coming from sensors is sent to the smartphone and processed by specific algorithms integrated inside the smartphone. Results from processing provide two classes of processed data. The first one is sent to the BRS to perform post-processing algorithms and get a more precise small-timescale trend behaviour recognized. The second one is sent directly to the cloud. These last data are more structured and collect more information because of their use by experts and ecosystem stakeholders.

Figure 2 specifies data that will be analysed to get small-timescale trend behaviour. The models that will form the outcome of this module will be able to represent physical activity and nutrition habits on a certain day. The interest of having small-timescale trend behaviour recognition is the possibility to rapidly react to the user behaviour (as explained in Section 4).

3.2. Long-timescale trend behaviour recognition

The turn from unhealthy behaviours into healthier new ones has to be monitored through technology over a longer period. As well as the user, the models defined in this module will dynamically change along with the user status, objectives, motivations and relations. In doing so, trends and patterns across the long term will be ex-

tracted. In other words, intelligent algorithms aimed at studying the long timescales of users and their behavioural trend will be defined.
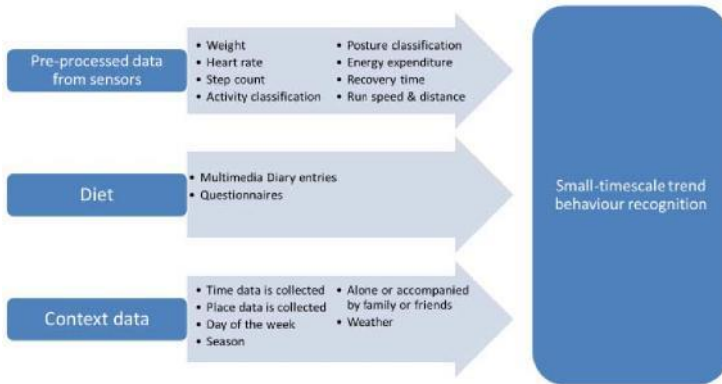

Figure 2. Analysed data

Those algorithms will be able to recognize habits, tastes, and preferences of the user and combined with statistical trend analysis the system will detect changes and distributions by applying frequent pattern-learning techniques. The algorithms will recognize alimentary, physical, and social behavioural trends to allow answering questions as: What type of exercise does the user do? When? How long? Does the user use social networks? How many hours is the user watching TV, using the computer or mobile phone? What is the mealtime on the different typical days? What is the amount of calories per meal, the type of food? Et cetera.

3.3. Mining habits and defining risk factors

One of the challenges of this project is to extract knowledge from sensors data streams and context data in order to both facilitate the subsequent decision-making and infer valuable information. In this case, the objective is to infer both physical activity and dietary user habits. To achieve this, it is proposed to mine datasets to build eﬀective data mining models taking into consideration all the relevant context factors for finding patterns and regularities in this sets of data.

3.3.1. Physical activity habits – Tuning of the activities detected by the sensor system

The sensor platform and the BRS will provide a robust suite of activity recognition algorithms to produce automated inferences on raw data. Basic services, such as those related to location (positioning based on GPS and additional algorithms to infer posi-tion in the absence of the GPS signal) and basic motion sensors to detect physical activity (e.g. accelerometer and gyroscope), are mostly provided through sensors em-bedded within the smartphone. The BRS will provide a module that will bring together data from the sensor platform to create an environment in which data can be read, analysed and interpreted. It comprises a post-processing system based on data clean-ing and data mining algorithms which will assure accuracy, completeness, uniqueness, timeliness and consistency. The former algorithms consist, on the one hand, on the automated detection of data glitches (multiple formats, missing/default values and gaps in time series) [12,13] and, on the other hand, on duplicate removal and value

standardization by applying semantic annotation. In particular, there will be established a number of connections for different measures into indicators for each element which will be underlying the model; for example, how different measures for blood pressure or glucose levels can be converted into one standard measure. The latter algorithms will apply decision trees and rule-based reasoning to get models that represent and predict user physical activity.

3.3.2. Nutrition habits

In addition to the above, also nutritional habits will be monitored. PEGASO does not introduce sensors to measure the food intake as the level of end-user acceptance is perceived as low [14]. Instead, questionnaires and a multimedia diary are planned to elicit dietary variables directly from the teens. The user will be asked to fill the Multimedia Diary providing information and data of the food they are going to eat by using a semi-quantitative food frequency questionnaire. The collection of nutrition information will be designed to be as simple and natural as possible and integrated to the system through a gamified approach. The collection of relevant information will be also actuated retrieving data from social web [15]. On the one hand, data mining algorithms will be adopted to analyse the questionnaires and diaries; on the other hand, suitable algorithms will be studied to verify the reliability of the acquired information.

3.3.3. Defining individual risk factors

Based on the elements composing the VIM, data acquired through the different components of the system will be analysed in order to define the individual's risk factors for being overweight and obesity and associated metabolic and cardiovascular co-morbidities. In particular, categorical data from physical, physiological, psychosocial and social status factors will be integrated with alimentary, physical activity and social behaviours expressed in appropriate scoring scales, to yield an overall dynamic and individualised risk. To analyse how multiple behaviours interact with each other, background knowledge will be gained through systematic review of evidence-based scientific literature and from the data generated by the pilot studies within the project. This will allow the definition of risk factors and the generation of predictive models for each individual, based on the tailored VIM representation and the identification of the most effective classifier. The system will take into account missing data on some elements that may determine the user profiles or the risk factors; e.g., the users might not know their blood pressure or choose to not use some sensors. In these cases, missing-data imputation methods will be used to replace them providing a suitable profile. The simplest way is to implement a country, sex and age-specific level of risk factors into the model, which will be the default in case of missing answers in the individual assessment. In addition, missing values will also be imputed based on answers to a few simple questions. This approach exemplifies a general feature of the proposed modelling which will implement techniques of iterative modelling and the more data will be inputted into the system, the better the guidance support and the better the predictions.

4. Motivation mechanisms

This section presents the motivations mechanisms that the PEGASO system will propose to the user. In particular, it describes how the information extracted from the data mining and reasoning approaches (small-timescale and long-timescale trend behaviour) will be used as feedback to the user to motivate a healthier life-style.

4.1. Short-term and long-term actions

The PEGASO system will be able to provide different kinds of feedback affecting small-timescale and long-timescale trend behaviours. In particular, the system differentiates the feedback in short-term and long-term actions.

Short-term actions are mainly related to small-timescale behavioural trends. These short-term actions are intended to respond to real-time information, coming from sensors or the direct user interaction with the system. An actuation mechanism could be as simple as raising an alarm or recommending the reading of some content to the user. Designing these kinds of interaction can be challenging, the *engagement loops* [16] is a model of activity loops helping the design of the interaction at an individual micro-level. Such a model is composed of three elements: motivation, action and feedback. If the motivation is strong enough, the user will act on the system (directly or indirectly) in order to accomplish a goal. As result, the system will provide a feedback aiming at reinforcing the user's motivation. If the loop is interrupted, several techniques are available to foster the desired interaction and re-establish the loop.

While short-term actions aim at responding to small-timescale behavioural trends, **long-term actions** are designed to induce an actual behaviour change in the user. In [17], Fogg proposes a model for persuasive design in which the behaviour is a product of three factors: motivation, ability and trigger. If the motivation is low, people will act only if the ability required is low, i.e. the difficulty of the action is low; on the other hand, if the motivation is high, people may act even if the difficulty is high. However, in the Fogg's framework, a trigger must be present to activate the target behaviour. A trigger can take many forms but it has the following characteristics: it has to be noticed, have a direct link with the target behaviour and have the right timing. In fact, the people motivation and, to a minor extent, the ability change over time and it is very important to have the trigger the right time. Finally, designers and, eventually, a system can operate on these three elements affecting the user behaviour. The reasoning approaches presented in Section 3 will assess the actual changes of the user behaviour and eventually correct the proposed motivation actions.

A key point in motivational approaches is the intrinsic motivation. Users *want* to change the way they behave, but they need some mechanisms to increase their motivation and to trigger the action. Sustainable behaviour change can be induced by the formation of habit associated to healthier behaviours. The design of the interaction cannot be limited to the simple triad *motivation, action* and *feedback*, but should also rely on more structured motivation mechanisms. Differently from the engagement loop, the *progression loop* [16] helps the design of long term, structured motivation mechanisms. The progression loop deals with the evolution of the user needs along with the interaction with the system, keeping the users engaged to the system.

4.2. Games and Persuasive technologies

Increasing the user motivation in having a healthier lifestyle and finally facilitating behaviour changes are the major challenges of the PEGASO project. Gamification and serious gaming are crucial design elements aiming at addressing these challenges.

Gamification refers to the application of game design-thinking, game mechanisms and game elements to non-gaming contexts, applications and problems [18] [19,20]. On the other hand, a serious game is a game whose primary purpose is other than entertainment and fun. The adoption of the smartphone as primary interface towards the user allows developing pervasive games that can link the physical activity to the dynamic of a game. Several studies in pervasive games achieved promising results increasing the motivation of participants towards healthier behavioural patterns [21,22]. Several of the pre-cited works have shown the positive impact of gamification and serious games in different contexts and for different targets. In addition, adolescents are even more likely to be engaged and interested from this kind of approach.

These approaches are developed in the frame of a recent interdisciplinary domain, known as Persuasive Technology [23]. Persuasive Technology focuses on the study of how the design and use of interactive technologies can affect the people behaviours through persuasion and not through coercion or deception. The PEGASO system will not be limited to game or game-like applications, it will suggest activities, propose informative and educative materials, promoting *health literacy* and education [24], and provide insights about the information acquired.

5. Conclusion

This paper presented a part of the PEGASO project dealing with the realization of a personalised and motivational ICT system aiming at empowering the adolescents towards healthy lifestyles. The user model, the VIM, is based on a conceptual framework grounded on the individual's physical, functional and behavioural aspects. This model is enriched and tailored on a specific user through reasoning on information acquired through a sensing platform, questionnaires and specific applications. Small-timescale and long-timescale trend behaviours are recognized, analysed and used to generate specific motivational feedbacks. In particular, the PEGASO motivation system is based on persuasive technologies such as serious games and gamified applications to promote health literacy concerning healthy alimentation and physical activity.

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