Personalized Guidance for People Empowerment and Self-efficacy towards Healthy Lifestyles
The Solution Proposed in SEMEOTICONS

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Abstract: This paper discusses the problem of fostering lifestyle changes towards healthier habits by means of coaching and supportive messages in the frame of a tailored users' guidance. Starting from the importance of behavioural changes to foster wellbeing and disease prevention, the main aspects of tailored users' guidance are reviewed, with a brief overview of the methods presented in the literature. The solution proposed in the EU FP7 Project SEMEOTICONS is then presented, discussing its advantages with respect to the state of the art.

1 INTRODUCTION

Primary prevention, in terms of lifestyle interventions, has demonstrated to be the best strategy to effectively modify the main patho-physiological factors responsible of the genesis of the most common chronic and disabling diseases. Indeed, if we would exercise regularly, eat healthy, control the stress, not smoke and moderate the use of alcohol, about 90% of type II diabetes, 80% of coronary heart disease, and 70% of stroke could be prevented (Sassi and Hurst, 2008). These evaluations have fueled, in the last years, public initiatives to promote psycho-physical wellbeing, such as the European Digital Agenda planned for the next years (EC Digital Agenda, 2013).

In this frame, ICT-enable technologies are seen as "the most powerful ally" to foster people self-emporewment and make them active actors in mantaining healthy lifestyles. Indeed, maintaining a healthy lifestyle frequently needs the counselling and supervision of various health professionals such as dieticians, physical trainers, psychologists and behaviourists. Such a prevention strategy is individually tuned and requires an expensive organization of the health systems. A rationale alternative to this kind of intensive individual coaching is the development of ICT systems for self-learning and self-monitoring. These solutions are mainly based on the acquisition of daily survey data about individual's behaviour and, accordingly, they provide tailored suggestions about nutrition, weight, physical activity, tiredness, and stress. Data collected by such coaching systems could be analysed and interpreted by health care professionals so as to support decision making targeted to the specific individual conditions.

To be highly effective and have favourable impact on large-scale prevention of chronic diseases, these systems might incorporate suitable personalized coaching mechanisms able to cope with individuals' variability, personal peculiarities and preferences.

It is in this frame that the EU FP7 Project SEMEOTICONS – "SEMEiotic Oriented Technology for Individual's CardiOmetabolic self-assessmeNt and Self-monitoring" poses itself as an innovative ICT-based solution: the project will develop a beyond-the-state-of-the-art multisensory device which will be able, from one side, to acquire individuals' physiological data in a contact-less and unobtrusive fashion and derive from those an evaluation about individuals' wellbeing status, and, from the other, it will provide personalized user guidance towards the maintenance of healthy lifestyle. This paper reports an overview of the overall project approach to this issue and presents the solutions that are currently under investigation.

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The paper starts with a discussion about the quest for personalized user guidance. Then, the SEMEOTICONS solution is introduced and the approach to personalized guidance presented. Discussion and conclusions conclude the paper.

2 TAILORED USER GUIDANCE

The quest for personalized user guidance towards healthy lifestyles moves towards the concretization of a paradigmatic scenario as the one proposed in (Honka *et al.*, 2011): the possibility to have a kind of *health navigator* able to guide the users through their day and assist them in making healthy decisions. Such a navigator, just like the GPS navigator, "would locate users on their individual health map, calculate the possible routes to improve one's health, and continuously monitor and recalculate the route, if users are not on the intended track".

Two main ingredients of this "futuristic device" are (*i*) the ability to acquire and interpret data about the current health status of an individual, and (*ii*) the capability to provide convincing and motivating messages that encourage an individual to recover or move to the desirable track, by changes in lifestyle.

The main challenges for the former issue, from a user oriented viewpoint, are mainly related to the ease and comfort of data acquisition and processing. ICT advances are going in a good direction in this respect, permitting the development of less and less invasive sensors and more and more fashionable devices (Hekler *et al*., 2013).

The latter issue is, on the contrary, much trickier, since it depends on the evaluation of a person wellbeing and health status and on the definition of effective guidance applications which requires merging together methods and theories belonging to different disciplines, such as psychology, motivation and communication science, social marketing, and behavioural theories and economics.

Lifestyle and behavioural changes are, in general, complex processes that require critical decisions by an individual who should be strongly motivated and encouraged. Only if aware of her needs and conscious of her capability to succeed, a person will be strong enough to go through with the change process. Social and contextual stimuli to maintain the correct behaviour are also determinant factors that should support this process. Personality, habits and contextual situations (e.g., stressing work circumstances) can, on the contrary, bias the success of the change.

In this overall picture, user-centred approaches, which are able to supply a strongly tailored support, are the most viable solutions. The idea is to maximize self-efficacy: the person's level of confidence that she can perform a specific task or move to and maintain a healthy behaviour in the future. Indeed, tailored information has been proved to be more effective in giving consumer information and is generally preferred by patients (Noar *et al.*, 2011). As is generally understood, tailoring involves a combination of strategies and information intended to reach *one specific person* based on characteristics that are *unique* to that person, related to the *outcome* of interest, and derived from an *individual assessment*. Profiling the individual user becomes essential in this frame. Dynamic tailoring using iterative assessment and feedback is an important intervention strategy. Multiple behaviours can be targeted simultaneously without hindering intervention effectiveness.

So far, several ICT applications have been developed for behavioural change; they have been labelled *personalized guidance/support systems* (PGS), and defined as information systems able to foster or adjust attitudes, behaviours or compliance (Oinas-Kukkonen, 2010). Usually, they employ technologies coming from a blending of conventional decision support and tele-monitoring systems.

The solutions proposed thus far can be mainly grouped in Internet-based, mobile-based or game-based interventions. For a detailed review please refer to (Krebs *et al*., 2010; Honka *et al.*, 2011). In particular, mobile-based solutions are more and more emerging, thanks to the feature of modern smart phones and smart mobile devices of incorporating several sensors and offering high user interactivity and multimedia facilities (Krishna *et al*., 2009; Riley *et al.*, 2011). Thanks to the enjoyable and appealing experience they offer, videogames have the ability to attract and engage the user and have demonstrated to have the strong potential to succeed in improving patients' skills and empowerment in disease management and rehabilitation (Kato, 2010). Although only few studies have been carried out so far to assess the real effectiveness of videogames for behavioural changes, they are for sure the best way to reach the youngest users (Ceranoglu, 2010) and offer the most appealing way to present tailored suggestions (Cannon-Bowers *et al*., 2011).

Several health domains have been tackled by the proposed PGS solutions: disease management (Gibbons *et al*., 2011; Fjeldsoe *et al*., 2009),

psychotherapeutic use (Andrews *et al*., 2010; Barak *et al*., 2008; Mitchell *et al*., 2010), health behaviour change (Webb *et al*., 2010; Cugelman *et al*., 2011). In the latter case, smoking cessation, physical activity, dietary practices are the most targeted concerns.

However, regardless of tailoring method, the effects of ICT-based intervention have been found overall to decline after intervention completion, suggesting the need for innovative techniques to help participants maintaining changes.

In this frame, there is the need of proactive methods able to aggregate data from advanced sensing framework, to recognize trends, and to support constantly the users with effective tailored guidance and information.

3 SEMEOTICONS PROPOSAL

The solution proposed in SEMEOTICONS goes just in this direction, since it comprises a self-monitoring device able to ensure a comprehensive approach to individuals' lifestyle changes and to keep the usage rate also after the first period of interest.

More precisely, SEMEOTICONS core idea is to develop an *interactive smart mirror* able to move the *semeiotic* analysis of face signs from the office of medical doctors closer to individual's normal-life settings. This way, normal people are enabled to self-assess their personal wellbeing status, with particular concern to their cardio-metabolic risk. Indeed, the face is an efficient discloser of important clues about a person healthy or unhealthy status. In particular, the face semiotics is a potential source of information for surrogate markers of obesity, metabolomics, cardiovascular homeostasis and psychophysical status, which are related to cardio-metabolic risk factors. The main goal of SEMEOTICONS is just to exploit the valuable pieces of information conveyed by human face systematically in a smart system able to help people in their daily life. To this end, a multisensory smart mirror, a kind of "*wise wizard*" mirror, called *Wize Mirror*, is being developed to be easily integrated, as a piece of house-ware, at home, or at different levels of the health care delivery chain, including fitness centres, nutritional centres, pharmacies, and so on. The Wize Mirror is being designed to supply a contactless evaluation of face signs by acquiring and processing heterogeneous, multimodal data about the exterior aspect and shape of the face as well as more in-depth characteristics mainly related to the composition of face skin levels. More precisely, the mirror seamlessly integrates contactless sensors, such as three-dimensional optical sensors, a multispectral camera, gas detection sensors, and microphones. A touch-screen interface is also included for user's interactions and output visualization. Data are mainly collected in the form of videos, images and gas concentration signals, and processed to extract a number of biometric, morphometric, colorimetric, and compositional descriptors which assess individual's facial signs. These signs correspond to the main cardio-metabolic risk factors, such as overweight, hypercholesterolemia, hyperglycaemia, impaired vascular homeostasis, psychological status (i.e., stress, anxiety and tiredness) and noxious habits (see Figure 1).

All these descriptors are planned to be suitably integrated to form a *Virtual Individual's Model* used to compute and trace the daily evolution of an *individual's wellness index*. A health diary about

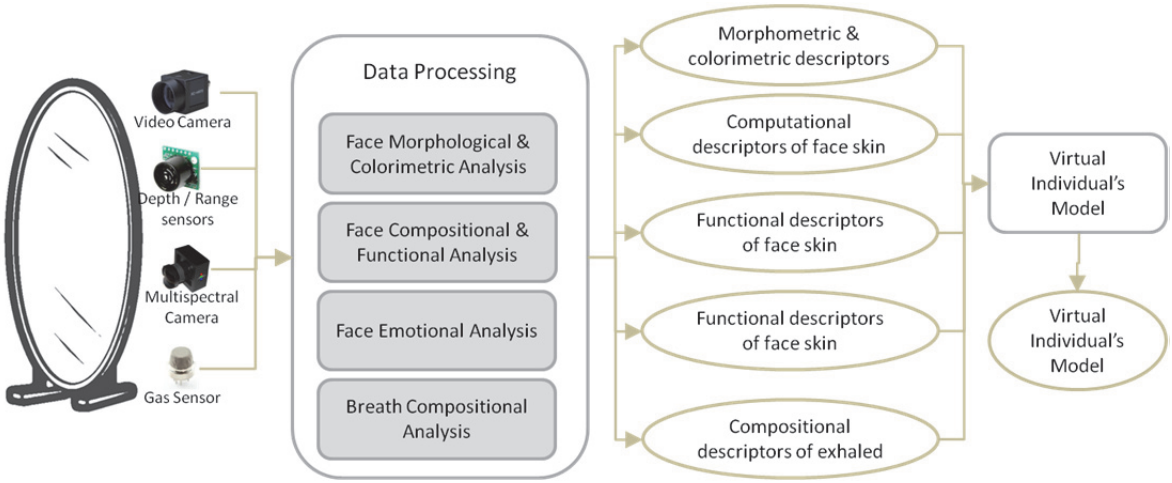

Figure 1: A sketch of the data acquisition and processing chain of the Wize Mirror.

this index is planned to be created so as to enable the individual to evaluate and personally relate her lifestyle to her wellbeing. Suggestions and coaching messages are to be also provided, in relation to the evolution of the wellness index and each descriptor.

Three main features characterize the resulting semeiotics-based well-being evaluation: it (*i*) is non-invasive, (*ii*) requires just a natural interaction between the subject and the system, (*iii*) supports and guides personal choices towards improvements and maintenance of a healthy life style.

Indeed, the development of the Wize Mirror takes into account the most important factor for a successful implementation: the final user who is going to benefit from this technology.

Just think about this scenario: *Dave wakes up and goes to his bathroom to prepare to the day to start. As usual, he stands for few minutes in front of his mirror, thinking about all the things that he has to accomplish during the day and he hear*:

"*Good morning Dave, lots of things to do today! You look a bit tired; I see some signs of stress and fatigue on your face and your eyes. I guess you are having a very stressful period. Why don't you try to take some time just for yourself? In your agenda, there is room from 5 to 6 p.m. to go to gym. May I plan this for you? To have a full energy, you can have a lunch organized in this way...*"

This is just a very easy example, which discloses the usefulness of having a device able to assess the wellbeing status of an individual in a completely not intrusive fashion. This peculiar aspect of the Wize Mirror, which increases the usability factor of the device, represents a significant step forward with respect to existing solutions, which often require the user to wear obtrusive electronic systems to gather data. Moreover, the Wize Mirror application sees the user at the centre of each design and development stage. The non-invasiveness of the system and the natural interaction pattern (looking into a mirror) strongly encourages the profitable adoption of this device. The Mirror is meant to display the results of the semeiotic computational analysis according to an intuitive and easy-to-read representation of a set of comprehensive indicators and a wellness index. The Graphical User Interface displays the results of the well-being evaluation as well as the suggestions of a Personalized Guidance System.

The system is being designed to be a multi-user device, e.g., shared among the members of a family, or used in pharmacies and fitness centres. Methods to automatically recognize the user are being evaluated in this respect.

3.1 Personalized Guidance Module

SEMEOTICONS PGS is being designed to be a kind of *personal health navigator towards wellbeing*, and thus complements the evaluation of individuals' wellbeing status with the provision of pertinent information and suggestions that support and supervise individual's self-monitoring.

The personalized guidance, based on user profiling in terms of preferences and attitudes, is being implemented to supply advices and counselling messages towards behavioural changes. Educational materials are planned to be conveyed as well to help relating individual's signs with correct behaviours and lifestyle. Tracking user's progresses in the improvement of her wellbeing descriptors and highlighting the successes that a user has achieved is meant to motivate the individual to use the device and to keep her wellness index high, thus leading to a better style and quality of life.

Figure 2 sketches the main components of SEMEOTICONS PGS. Such components mainly correspond to the main processing steps of the system, i.e. accurate profiling of users, estimation of the wellness index, provision of personalized guidance.

In particular, the user profiling along with the descriptors extracted from the acquired data composes a *Virtual Individual's Model* (VIM) used to estimate the wellness index. Indeed, the VIM complements the user profile, to be considered also as the starting baseline evaluation, with a global picture of individual's wellbeing status obtained from these descriptors with respect to the cardio-metabolic risk.

Users' Profiling. As stated in the previous section, in order to be effective and sustainable, user guidance needs to be tailored to the individual's needs and characteristics. Profiling the user is determinant in this respect. In particular, in SEMEOTICONS PGS, the user profile has a twofold value, since it is meant to be used to:

i. assess the health status of the user at the starting point, when she will start using the Wize Mirror. In this respect, it includes all the information pertaining to the individual's health behaviours and clinical risk factors, including the genetic susceptibility and family history of cardio-metabolic diseases;
ii. identify users' characteristics, attitudes, habits and preferences so as to select the best strategy to provide suggestions and coaching messages, and find solutions that motivate to engage with the behaviour change process and identify the barriers that should be worked out.

In the most advanced settings under investigation

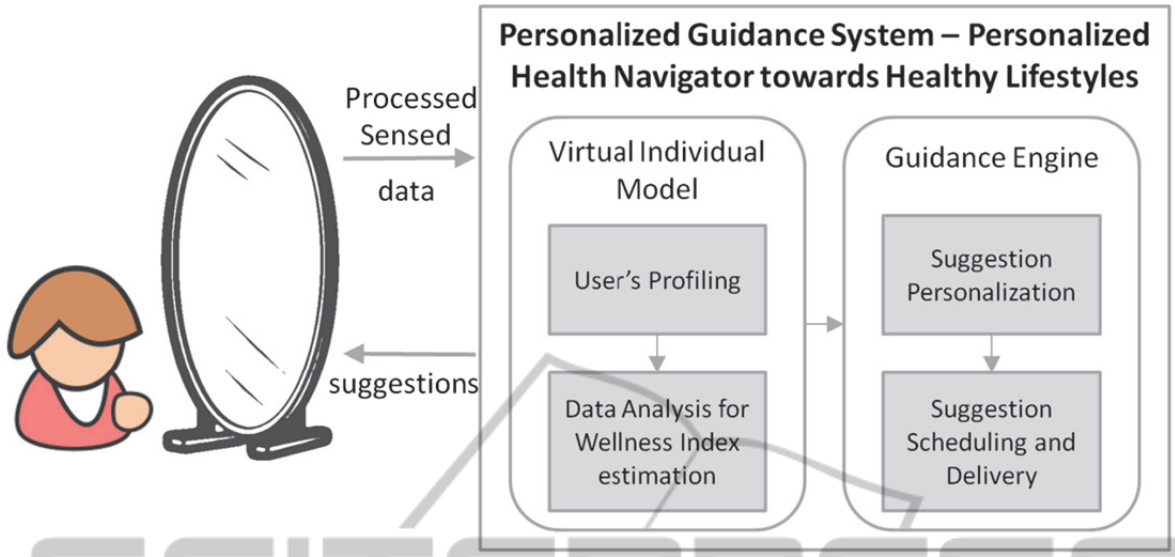

Figure 2: A sketch of SEMEOTICONS Personalized Guidance System – a kind of Personalized Health Navigator towards healthy lifestyles.

the personal profile is dynamic, taking into account contextual changes. In particular, since the Mirror will be a static device, contextual awareness is here to be meant as the possibility to take into account the evolving circumstances and situations that the user can go through, e.g., stressing working or emotional periods. For the same reason, direct means are mainly considered to collect data about the users, i.e., questionnaires. In this respect, several already available and well-assessed questionnaires are being evaluated to measure different aspects of physical, social and mental health, quality of life, behavioural risk factors, other determinants of behaviour, and personal characteristics, such as personal motivators.

To understand contextual circumstances, personalized questionnaires can be envisaged in correspondence with the detection of specific signs from the acquired data, e.g., stress or tiredness, increased weight.

For the definition of the users' profiles, several approaches are being investigated, including overlay models (Brusilovsky and Millán, 2007), computational methods (Castellano *et al*., 2007) and ontologies (Tahir *et al*., 2013), with a preference for the hybridization of the latter two approaches.

Wellness Index Estimation. The VIM integrates all the descriptors extracted from the sensed data, starting from and according to the user's profile.

The descriptors correspond to an evaluation of face signs produced by the main cardio-metabolic risk factors (see Coppini et al., 2014). In particular, the following traits of an individual's face will be evaluated computationally (see Figure 1):

- face morphology and colorimetry to identify signs of obesity and psychological status;
- face skin composition to identify signs corresponding to hyper-glycaemia and hyper-hypercholesterolemia;
- face skin functionality to evaluate endothelial function;
- face expressions to identify signs of stress, anxiety and fatigue;
- other general face traits allowing for the computation of heart rate and heart rate variability;
- exhaled composition to identify noxious substances.

All the descriptors are condensed into a wellness index, easily displayable to the user, so as to correlate the evolution of semeiotic signs to individual's cardio-metabolic status.

The wellness index represents a non-diagnostic estimation of a user's health status, meaningful for self-assessment and self-monitoring purposes. To this aim, its temporal evolution is tracked to define a wellbeing diary.

A proper multidimensional space, the *cardio-metabolic wellbeing space*, is being defined to track the relevant measurements and to extract meaningful values representing the wellness status. This point is quite innovative, and, even if the wellness index extracted is not intended to be used for diagnostic purposes, it is going to be released as a reliable indicator of the cardio-metabolic risk.

Suitable machine learning methods are under

investigation for analyzing, understanding and transforming the multidimensional vector formed by the computational descriptors, e.g. non linear mappings. This way, the most significant information are extracted and conveyed into the index. It is worth noting that the wellness index is being defined to encompass the temporal evolution of the computational descriptors of facial signs.

To validate the results of the wellness index estimation, well-established cardio-metabolic risk charts (e.g., HEART SCORE, Fatty-Liver index, HOMA index, FINRISK index) are being taken as validated ground-truth.

The visual representation of the virtual individual's model, i.e., an expressive way to represent the wellness status, is being designed and developed, tailored on the subject's preferences/attitudes. It could vary from a very simple and friendly visualization – like a comic; to a more 'scientific' one – a sort of augmented subject's photorealistic visualization.

Personalized Guidance Provision. SEMEOTICONS PSG is meant to provide personalized suggestions and messages, in accordance to (*i*) the estimated wellness index and its variation over time, (*ii*) the user's profile in terms of attitudes, habits and preferences and (*iii*) possible contextual information related to user's life circumstances, the system.

For example, the system might (*i*) either suggest to contact the general practitioner, due to a serious worsening trend of the index or (*ii*) reward and encourage the individual subject that is maintaining a good wellness index or (*iii*) display dietary suggestions and/or workout plans, or (*iv*) supply specific suggestions according to specific signs detected, and so on.

This personalized user's guidance, strictly coupled with the correlation of the wellness index to established cardio-metabolic risk charts, is planned to be specifically tuned to foster the prevention of cardio-metabolic diseases.

The coaching messages and the information provided with them are meant to foster

- awareness and comprehension
- abilities and empowerment.

More precisely, the suggestions aim to make the user aware of the benefits and risks associated with various options. This is planned to be done with simple, concrete, correct and high-quality messages, tailored to users' characteristics so as to influence information intake and user engagement. Moreover, the proposed interventions are meant to be posed so as to let the users gain greater control over the decisions and actions affecting their health.

The presentation, visualization and linguistic style of suggestions are studied to be in accordance to users' peculiarities, since they are important moderators in communication modalities. For instance, they take into account users' attitudes to be anxious, hypochondriac, tending to depression or cheerful and social.

Inspiration for personalizing the suggestions styles are being drawn from game design strategies with the twofold aim of being appealing and attractive and of reinforcing engagement and maintaining the interest high.

Techniques used in recommender systems are under investigation and a proactive decision support system is being studied, exploiting both procedural knowledge (formalized through ontologies and open standards provided by the semantic web communities) and computational models.

A lightweight inference engine is being designed to reason on the procedural knowledge and produce relevant suggestions, while computational models to be used to address less formalized and unstructured decisional tasks. Such core decision support system natively provides personalized guidance; indeed the procedural knowledge is being designed to be adaptive and to best adhere to user's psycho-physiological status, attitude and inclination.

4 DISCUSSION AND CONCLUSIONS

ICT applications to foster behavioural changes have shown to be effective tools to implement primary prevention, meant as the promotion of healthy lifestyles. This type of prevention, actually, appears nowadays as the most viable strategy to reduce the socio-economic burden of chronic and widespread diseases, such as cardiovascular and metabolic diseases.

However, developing successful applications is a non trivial task, which requires merging methods and theories from several disciplines, including computer science, psychology and marketing.

In this paper, we have discussed the main issues that arise when dealing with this problem and presented the SEMEOTICONS solution.

In particular, thanks to the main features of SEMEOTICONS' expected results, such solution appears promising. Indeed, it is based on a completely non invasive evaluation of the health status of the user, by means of a multisensory device having the exterior aspect of a mirror. This can be easily integrated as a piece of houseware and is

characterized by three main features (*i*) non-intrusiveness, (*ii*) natural interaction with the user, (*iii*) provision of tailored support to personal choices towards improvements and maintenance of healthy lifestyles.

In particular, the tailored support is being studied to overcome the usual shortcomings of behavioural change applications. Indeed, the suitable selection of the presentation, visualization and linguistic style of suggestions are being studied to be in accordance to users' peculiarities, since they are important moderators of effect in communication modalities. Moreover, personalized guidance services are meant to be provided continuously and on a daily basis, helping people to maintain achieved changes and, thus, overcoming the limits in endurance of other attempts presented in the literature.

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