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Personalized Behavior Change Support for Disease Prevention

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***Abstract*—Healthy lifestyle is essential in prevention of chronic diseases. However, people need motivation and support to achieve and to maintain behavior changes. Moreover, effective behavior change support should be personalized to individual's unique characteristics, needs and context. This paper presents a blueprint of an ICT system, which is able to provide holistic, dynamic support for healthy behaviors, engaging also various co-producers in the health journey of a person. Three main concepts in the system are Virtual Individual, which maintains the user's personal profile, PGS-Mall, which collects various health and well-being services into one place, and HealthGuides, which support healthy choices in everyday life and coordinate the interactions between the user, the system, and other co-producers of health.**

I. Introduction

THE global burden of disease is increasingly caused by unhealthy behaviors. The five leading risks for mortality worldwide are high blood pressure (13%), tobacco use (9%), high blood glucose (6%), physical inactivity (6%), and overweight and obesity (5%) [1]. Non-communicable diseases, especially cardiovascular diseases, diabetes, cancers, and chronic respiratory diseases, accounted for 60% of all deaths in 2005 [2]. To a large extent, these diseases and premature deaths could be prevented by adopting healthy lifestyles.

However, behavior change is a challenging task, since people tend to prefer short-term gains such as delicious taste to delayed consequences such as long-term health benefits [3]. Moreover, established unhealthy habits are hard to break, especially if social and physical environments do not give support to attempts to make healthy choices [4]. Hence, health promotion initiatives need a thorough understanding of what can be done in order to encourage and support people to change their unhealthy behaviors and to maintain healthy habits in their everyday lives.

The PREVE project [5] set out to reach this understanding and to identify research directions for ICT services which support health behavior change. The project comprised of three phases: identification of 1) the most prevalent lifestyle-related diseases and the best practices in their prevention, 2) effective behavior change intervention approaches for different behaviors and individual characteristics, and 3) feasible business models and technical requirements in ICT-enabled disease prevention. In each phase, an extensive literature review and analysis was carried out.

The results of PREVE function as a basis for a further research agenda. The detailed deliverables, including the White Paper on research directions, can be found at http://www.preve-eu.org/. The key messages which emerged from the findings are summarized below.

1) In everyday life, people are constantly faced with numerous choices which affect their health. Various co-producers of health such as family, friends, school, workplace, food markets, media, policy-makers and healthcare influence daily decisions. Hence, people are actively contributing to their own health and well-being, instead of being passive targets for treatment. This paradigm was coined as *Citizen as a Co-producer of Health* (CPH) model.
2) Rules of the game need to be changed to create a sustainable *Health Outreach* ecosystem in primary prevention. This means expanding and restructuring value networks and business models to involve all stakeholders and co-producers and to give them incentives to work together to support healthy choices in daily life. The creation of supportive environment also requires changes on the societal level. These changes can be set in motion by using e.g. health advocacy strategies [6] to make policy changes and to tackle socioeconomic issues.
3) *Full personalization* is required for effective behavior change support. Support mechanisms need to be integrated into a person's everyday life and adapt to personal needs, values, characteristics, interests, and changing life situations and contexts.

ICT has a major role to play in creating the Health Outreach ecosystem and a personal guidance system (*HealthPGS*) which could provide personalized support for people as well as serve the needs of co-producers in their environment. Fig. 1 presents the blueprint of a HealthPGS system which coordinates the interactions between individuals and their environments. The following chapters describe the system and its components in more detail.

II. HealthPGS System

The HealthPGS system can be compared to a personal navigator on a health journey. For the user of the system, it provides personalized guidance and motivation, recommends appropriate services and connects the user to them, and collects and analyzes data to adjust its guidance. For service providers and other co-producers of health, it offers added value by integrating them into a tight network in which data is exchanged and shared, allowing each party to focus on their unique offering.

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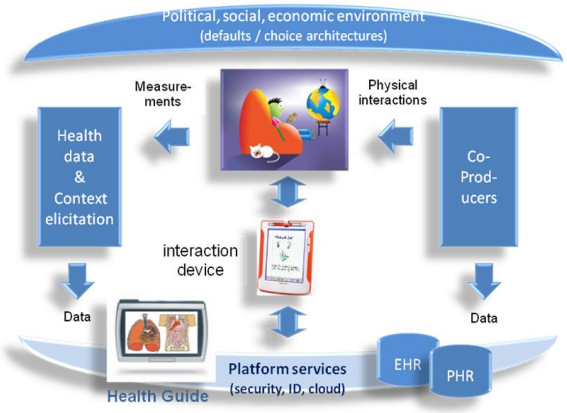

Fig. 1. The scenario of ICT-enabled disease prevention with the HealthPGS system.

The HealthPGS system components operate on a flexible platform, which handles the interactions between them through a common API, and ensures that security and privacy requirements are met. The essential high-level components are:

- **Virtual Individual,** which maintains the dynamic profile of a person.
- **PGS-Mall,** which is a repository of health and wellness related applications, products, services, and intervention models.
- **HealthGuide,** which provides personalized behavior change support based on the user's profile and context, and coordinates interactions between co-producers.

The user interacts with the system through the HealthGuide which collects and analyzes data, matching intervention goals and behavior change support mechanisms with the user's personal profile (the Virtual Individual).

The requirements for HealthPGS system components are described in the following chapters and reflected to the current state of ICT to identify gaps between current technologies and the requirements, and to pinpoint new research directions.

III. Virtual Individual

The idea of creating an extensive user profile for personalized guidance, the Virtual Individual (VI) model, is based on behavioral science theories and evidence of effective health interventions. The benefits of personalization and tailoring of intervention methods and contents is well known in health promotion and communication research. The rationale is that an approach which is tailored to individual characteristics such as needs, interests, and abilities has a better chance to encourage attitude and behavior change. For instance, a message which is adapted to a specific person is viewed as more personally relevant and is more likely to be cognitively processed [7]. Recent meta-analyses have indeed concluded that tailoring is generally effective across various health behaviors [8,9].

The VI model is a dynamic representation of the user's physiological, psychological, social and behavioral characteristics as well as her individual risk factors, preferences and goals. The purpose of creating such an extensive model is to gain a thorough understanding of the user's unique needs and life situation. Through this understanding, the user can be offered fully personalized, adaptive support in health behavior change.

The VI model should incorporate variables which can effectively guide selection of intervention approaches, especially the specific factors, which influence behavior. In PREVE project, various behavioral science theories and frameworks were reviewed to identify the essential determinants of behavior. It was found that no single theory prevails, but instead theories overlap and complement each other. Thus, the available knowledge was synthesized into a hybrid model containing the key determinants (Fig. 2).

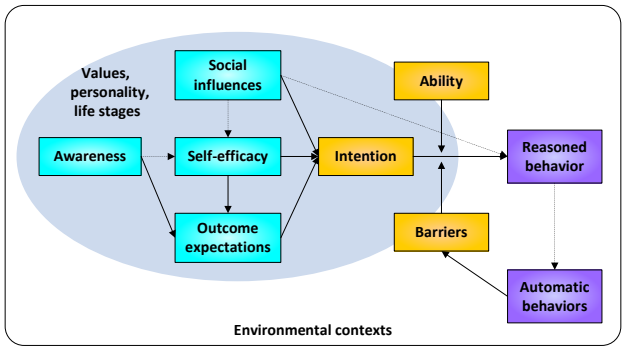

Fig. 2. Determinants of behavior and the relationships between them.

According to the model, the main determinants of behavior are intention, abilities, and barriers, whereas the other determinants in Fig. 2 influence mainly intention. The identified determinants form the basis for the VI model, the profile of a person, which incorporates the following constituents:

- Current **health behaviors** and **risk factors**. These determine intervention needs and goals for a person.
- Degree of **intention** towards healthy behaviors; the readiness and motivation to change behavior.
- Personal **motivators** and values. Healthy behaviors need to be aligned with a person's primary goals and interests in life, and presented in an appealing way.
- **Resources** (abilities and barriers). These include a person's internal resources such as psychological and physical abilities, and external resources such as available facilities and services, monetary resources, time constraints, and social support.

Technology-mediated interventions in health domain have thus far been generally limited to a small amount of variables in how they profile users and tailor interventions. On the other hand, user-adaptive software systems [10] in domains of e-commerce and e-learning have gone far in modeling user features such as knowledge, interests, goals, background information and individual traits as well as contexts. Social marketing research has also focused on

targeting interventions based on individual motivators and resources [11]. Development of the VI model needs to combine the knowledge from these different fields.

Semantic interoperability is another challenge in utilization of the VI model, since it requires acquisition of data from various sources such as EHRs, PHRs, sensors, user input and applications, and needs to be able to exchange data with various services in the HealthPGS system. Existing standards and ontologies are mainly concentrated on disease care. Further work is needed to expand them to incorporate new data types related to behavioral aspects outlined above.

IV. PGS-MALL

The premise of CPH model is that co-producers of health and their services are joined together and interact with each other in a shared environment. Currently, there is a vast amount of services, devices and applications available for management of health behaviors. For example, there is a huge number of applications related to health or wellness in iPhone AppStore and Android Market. However, most of the applications do not interact or share data with each other. Furthermore, most applications or devices only collect one or two types of data [12] and are focused on a single behavior such as diet, physical activity, or stress management, leaving the responsibility of finding suitable combinations or analysing patterns and causalities between different behaviors to the user.

The purpose of the PGS-Mall is to collect all services into one place and to provide co-producers interfaces to add and update their offering. Since co-producer services can be more than single applications (e.g. food lists from local markets or wellness packages, which contain technology tools and group activities), ontologies and object models for these new data types need to be developed. Users should be able to find suitable services by browsing through different categories, and give ratings or comments on them. Even more importantly, the HealthGuide can recommend users services which match their personal profiles. Therefore the object models for PGS-Mall services should be built in collaboration with the VI model development.

V. HEALTHGUIDE

The HealthGuide is the central part of the HealthPGS system. The core processes that it runs are depicted in Fig. 3 as parts of a continuous cycle with four phases. Analysis and planning set the stage for execution of the personalized plan and progress evaluation with appropriate metrics.

- **Analyze** – The profiling component constantly updates the VI model with data acquired from various sources, covering various aspects of life.
- **Plan** – Intervention goals are determined based on the VI model constructs, and matching services are located in the PGS-Mall based on the goals as well as the motivators and resources of the user.
- **Execute** – Behavior change support is provided through PGS-Mall services and various support mechanisms built in the HealthGuide, such as tailored information, reminders, and social support.
- **Evaluate** – Progress towards set goals is analyzed in light of the VI model to detect behavioral patterns, trends, causalities, and progress towards goals. Intervention plan, goals and methods are adjusted if there are changes in the situation or user needs, or the plan does not appear to be working as intended.

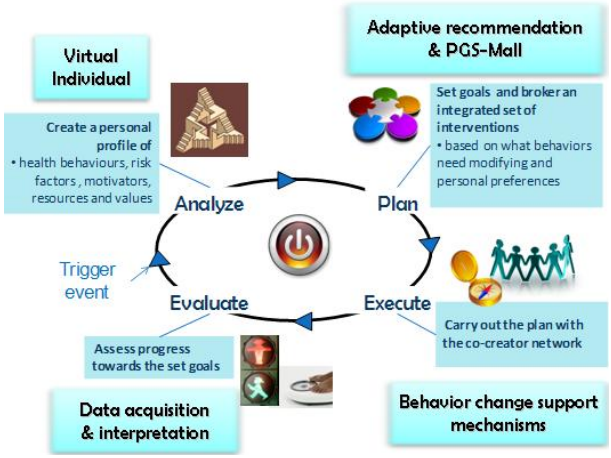

Fig. 3. The process through which HealthGuide supports behavior change and maintenance, interacting with the HealthPGS system.

Through these processes, the HealthGuide should be able to provide proper guidance and interventions for various combinations of specific conditions and behaviors. Research has shown that interventions are more effective if they are based on behavioral science theories [13]. These theories can and should be used to create intervention models and processes. The models should be extendable and re-usable, which requires abstraction of available knowledge into ontologies [14]. An example of intervention protocol modeling can be found in [15].

Special attention should be paid to how the user interacts with the HealthGuide. In general, health-promoting interventions should be as entertaining and engaging as the other activities with which they compete [13]. Healthy behaviors should be intrinsically motivating: pleasurable, fun experiences for the sake of the behavior itself. The knowledge about personal motivators and characteristics can be used to choose proper motivation and reinforcement mechanisms in user interaction. Users need to be able to interact with their HealthGuides through various channels depending on context and purpose. For example, context-aware mobile applications are essential when the user is on the move and needs guidance in immediate choices in specific situations, whereas Internet-based educational programs may be more suitable for contemplation and planning.

The HealthGuide uses various mechanisms to support behavior change, drawing from the field of persuasive technologies. This field is focused on studying the features

of behaviour change support systems, which are designed to bring about changes in attitudes, behaviors, or compliance [16]. Persuasive Systems Design model provides a framework for analysis and design of behavior change support techniques for motivation and skills improvement [17]. Techniques can be used to help users carry out primary tasks more easily, to facilitate human-computer dialogue, to strengthen the credibility of the system, and to leverage social influences (e.g. active participation of healthcare professionals, family and friends). With data derived from context-aware sensing technologies, support mechanisms can be used at opportune moments, when users are most likely in need of guidance and open to receive it.

VI. Conclusions

HealthPGS can also be visualized as an ecosystem which unites various service providers, co-producers and stakeholders together with the users of HealthGuides. It enables people to take responsibility of their health and well-being, aided by a personal guidance system as well as other people and actors who share the same goal of improving health. A lot needs to be done to fully realize personalized health guidance systems: it requires rearrangement of value networks in healthcare, coordination of fragmented health and well-being service market, and development of the HealthPGS system and its components.

On the other hand, a lot has been done already. Health consciousness is on the rise and there are numerous applications, devices and services related to health behaviors. Sound research-based guidelines for health promotion interventions exist. The logical next step is the integration of existing technologies, services and co-producers under the Health Outreach ecosystem. People make daily choices surrounded by a huge number of options, which need to be recognized in order to support the long-term maintenance of healthy habits. ICT can be used to model this full complexity of behavior and to influence behavior change.

HealthPGS also raises some serious ethical questions. Security and privacy of user data must be ensured, giving users also the possibility to switch the system off and to control what data is collected and with whom it is shared. The credibility of the system is another issue; HealthGuides and PGS-Mall services must be certified and adhere to technical, medical, ethical and legal regulations. In terms of behavior change support techniques, care must be taken in ensuring that they are not abused or used for malevolent purposes [16]. Furthermore, the HealthPGS system should not widen the well-known inequalities in health between those with low and high socioeconomic status. Affordable, accessible channels (e.g. SMS, web) for personalized health guidance should exist in addition to advanced interaction devices.

Finally, the level of personalization suggested by the VI model and the HealthGuide is a considerable research challenge. The proposed model incorporates a huge amount of variables, which generate a multitude of rules for tailored support mechanisms, context recognition and content delivery. Further research into tailoring will reveal the extent of personalization that can be achieved. Setting off towards the research directions presented here is likely to raise new questions and uncover new challenges along the way, and presumably also lead to improvements in people's health and quality of life.

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