

# Co-Production of Health in Smart Cities: The M3 Case Study

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**Abstract** — Personalized interventions that empower users through pertinent and reliable information - alongside ubiquitous and user-friendly services, interfaces and products - can provide users with the opportunity to adopt healthy lifestyle choices, which improve quality of life and help prevent a vast number of chronic diseases. This paper would like to present the case of the Mobile Medical Monitoring (M3) project as representative of the work carried out by the eServices for Life and Health research unit alongside the City of the Future Living Lab; this project was based on an eService design approach of deploying innovative ICT (Information and Communication Technology) and multi-device based services. The focus of this paper is therefore to explore the Engineering Awareness™ approach alongside the co-creation living lab methodology.

**Keywords:** *Co-production; ICT; Living Lab; eService design; Co-creation Living Lab process.*

## I. INTRODUCTION

The World Health Organization (WHO) estimates that chronic, non-communicable diseases (NCDs) are the leading cause of morbidity, disability and mortality across all countries of the globe, and that these are all related to an individual's lifestyle choices. As a result, there is an impellent need for medicine and the delivery of healthcare services to play a much more proactive role in an individual's life and to develop strategies that address the individual in a human-centric, non-intrusive and eco-sustainable manner in order to trigger long-lasting and healthier lifestyle-choices and behavior patterns.

This paper will initially address briefly those different strategies identified by the e-Services for Life and Health research department of San Raffaele Hospital (FCSR) which should be adopted in order to improve the way in which healthcare services actively participate in an individual's life; further on, the paper will briefly present the Mobile Medical Monitoring (M3) Case Study and how this service, embodying those strategies, had an effect on a study group.

## II. STRATEGIES FOR IMPROVING THE DELIVERY OF HEALTHCARE SERVICES

The strategies developed by the e-Services for Life and Health unit can be summarized as follows (and will be described in the upcoming paragraphs): a revisited and ICT-enabled and smart clinical assessment process; prevention through personalized information and education, together

with a more active role on the part of healthcare professionals; the adoption of a co-production approach.

### A. Transform prescriptions into an experience

In order to improve their efficacy in disease prevention as well as disease control and management, medicine and health delivery services need to play a more proactive role in an individual's life. To be able to understand the importance of adopting healthy lifestyle choices and behavior patterns in the prevention of disease or how to best manage a diagnosed condition and prevent it from becoming chronic, an individual must be informed and educated via a network of trustworthy healthcare professionals. The information provided by those figures of reference should be personalized and contextualized – reflecting an individual's real everyday needs and objectives – to avoid being viewed as impositions but rather as motivational triggers.

In order to provide such rich and targeted information, a 360° profile of the individual must exist, a profile which matches both medical data as well as lifestyle and personal data. In other words, a drug prescription should no longer be a list of medicines, doses and times of day in which they should be administered; rather, it should be a lifestyle prescription, composed of comprehensible, practical and actionable advice; it should also include on-demand continuous guidance that the individual can relate to at all times in a typical day and throughout his/her life. The doctor-patient relationship is thereby raised to a higher level of mutual collaboration, thus forming a Health Personal Guidance System (Health PGS).

At all levels of society, individuals may not necessarily have the proper skills to make informed choices or the appropriate culture to understand risks. At the same time, they may not have the opportunity to elaborate compatible alternatives (should those alternatives be offered to them). It is for this reason that personalized, contextualized and pertinent information and education are key in promoting responsible and conscientious lifestyle choices. Indeed, there are many examples and discussions in literature that address the concept that the greater degree to which interventions are personalized and involve highly-skilled medical experts the higher their success rate when compared to the impersonal interventions of mass media communication campaigns.

### B. ICT as a healthier ecosystem enabler

Such a detailed, individual profile will present healthcare professionals with an unprecedented amount of an personal

data, both medical and lifestyle-related. From a knowledge management perspective, a radical change in the structure of the Electronic Healthcare Record (EHR) systems will have to occur, evolving from the present semi-static paradigm into a completely different and much broader one, that eServices for Life and Health unit likes to call the Personal Health Record (PHR). The PHR must give structure to the rapidly growing, vast amount of dynamic patient data spread across a multiplicity of specialties and gained via a widespread set of actuators (including existing databases, the individual himself/herself, remote devices, embedded technologies and sensors, healthcare smart cards and so on), thus demanding exceptional levels of data storage, data protection, data visualization, decision support and analytical tools that can be enabled only by a total redesign of ICT platforms.

ICT platforms must therefore expand and embrace a multitude of fields of activities and meaningful data from industry, education, community participation, technical infrastructure and various soft factors [1] in order to produce an ICT network able “to transform life and work ... in significant and fundamental, rather than incremental, ways” [2], thus producing a Smart City which promotes and supports the prescription experience.

### C. A co-production approach

In a traditional sense, co-production in healthcare refers to the contribution of service-users to the provision of services [3]. It is an approach which challenges the usual relationship between professionals and service-users since it stimulates the latter to be considered experts in their own circumstances and therefore capable of making decisions and having control as responsible citizens [4]. Co-production also implies a change in the role of healthcare professionals, from fixers of problems to facilitators who find solutions by working with their clients [5].

The e-Services for Life and Health research unit and the City of the Future Living Lab have developed a model and a methodology that embody the essence of the co-production approach, bringing it to a new level where the end-user is truly an active participant in a healthcare service. The following two sections will address both these developments.

### III. ENGINEERING AWARENESS™

Engineering Awareness™ (Fig. 1) is a unique service design model that synchronizes emotions (a trigger to an individual's psychological reaction in context with his/her preferences) and relations (a trigger for a social interaction with other individuals physically present or not, and/or with a proximity or remote environment in context with his/her preferences) with regard to functions (an individual's practical need addressed by the service) delivered.



Figure 1. Engineering Awareness™.

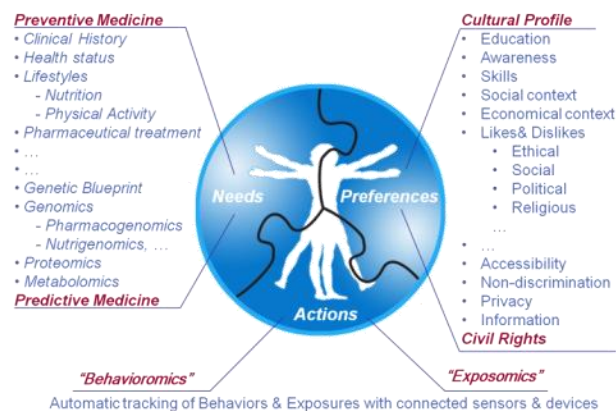


Figure 2. Engineering Awareness™, a model on health and lifestyles.

Designing for an individual's awareness and behavioral change is the primary ethical objective of any personalized service developed within the eServices for Life and Health unit. The mission of this research unit is not to manipulate individuals (i.e., making them do a supposedly "right thing/healthy thing" decided on their behalf by a knowledgeable third party) but to provide them with an unbiased understanding of the impact that a given decision/action implies. Each individual is characterized by his/her own digital profile, a complex, dynamic and progressive repository of personal data, information and events which is split into three parts as illustrated in Fig. 2:

- needs, i.e., the medical part of the profile: the genetic blueprint and the meaningful biochemical/physiological parameters of an individual that are considered relevant for a statistical health risk assessment at the level of state-of-the-art knowledge in primary/secondary preventive medicine and predictive medicine;
- preferences, i.e., the “personal preferences” section of the profile: the unique cultural resources of an individual, including his/her likes and dislikes and ethical beliefs;
- actions, i.e., “the health-related actions” part of the individual's profile: the unique (and constantly evolving) series of meaningful, health-related actions performed by an individual (“Behavioromics”) and exposures to environmental factors (“Exposomics”) in his/her daily life.

### IV. THE CO-CREATION LIVING LAB METHODOLOGY

The San Raffaele City of the Future Living Lab is an ecosystem within an area of 300,000 m<sup>2</sup> that can be described as a tertiary urban area (or a compact urban district) where all typical, daily operations are concentrated within a reduced space. The way it has been designed allows its research team to access, understand, study and measure the interactions among an estimated 27,000+ community of City of the Future daily-users (20,000+ a day turn-over of inpatients, outpatients and visitors of all ages and needs; 5000+ on-site employees, researchers, etc.; and 1700+ students).

It is both a virtual as well as real research environment and community, managed and organized by the eServices for Life and Health research unit. The Living Lab follows the conceptual framework presented by ESoCE-Net in which user-driven and open innovation is fully integrated within the co-creation process of new services, products and societal infrastructures [6]. As of 2012, the City of the Future Living Lab has been awarded membership of the Enoll (European Network of Living Labs) network.

Such a unique environment has been the field of international ICT research projects in 5th, 6th and 7th European Commission Framework R&D Programs and Italian/Lombardy Region R&D Programs since 2000, nurturing intense, cross-disciplinary collaborations among medical and healthcare professionals, designers, engineers, scientists, policy makers and entrepreneurs across a number of well-being, life and health-related fields.

Living Labs are innovation environments that focus on user communities embedded within “real life” situations and environments. The fundamental concept at the base of a Living Lab is to gain direct and unfiltered access to users’ ideas, experiences and knowledge, based on their daily needs and desires of feeling supported by products, services or applications. The Living Lab methodology ideated and put into practice by the City of the Future Living Lab is based on a revisited version of the traditional Living Lab methodology and is centered around a co-creation approach. Indeed, end users as well as stakeholders (including City of the Future

Living Lab designers, information technology and mechanical engineers, project managers and ethnographers, as well as pediatricians, psychologists, dieticians, physiotherapists, sociologist, nutritionists, teachers, marketers and so on) are actively involved throughout project ideation, exploration, implementation and experimentation. Such an approach was chosen because the City of the Future Living Lab firmly believes that users and stakeholders should influence the design process so that what comes out of it is a solution that can respond effectively to their needs and fit into their everyday lives. Insights are gathered directly from the users in order to define and implement realistic, useful, desirable and effective artifacts.

The Co-Creation process ideated and developed by the City of the Future Living Lab is based on four concurrent phases (Fig. 3): Co-design; Implementation; Experimentation; Evaluation. Since this approach is an iterative and reflective one, a starting point remains undefined, and the Living Lab process can be commenced at any stage of the design activity.

### V. M3 CASE STUDY

Mobile Medical Monitoring (M3) is project funded by the Italian Region of Lombardy. It consists of a wearable patch, shown in Fig. 4 (composed of a durable part to which standard electrodes can be attached), a smartphone and tablet app and web portal. It is a service where users (both professional athletes as well as average individuals)

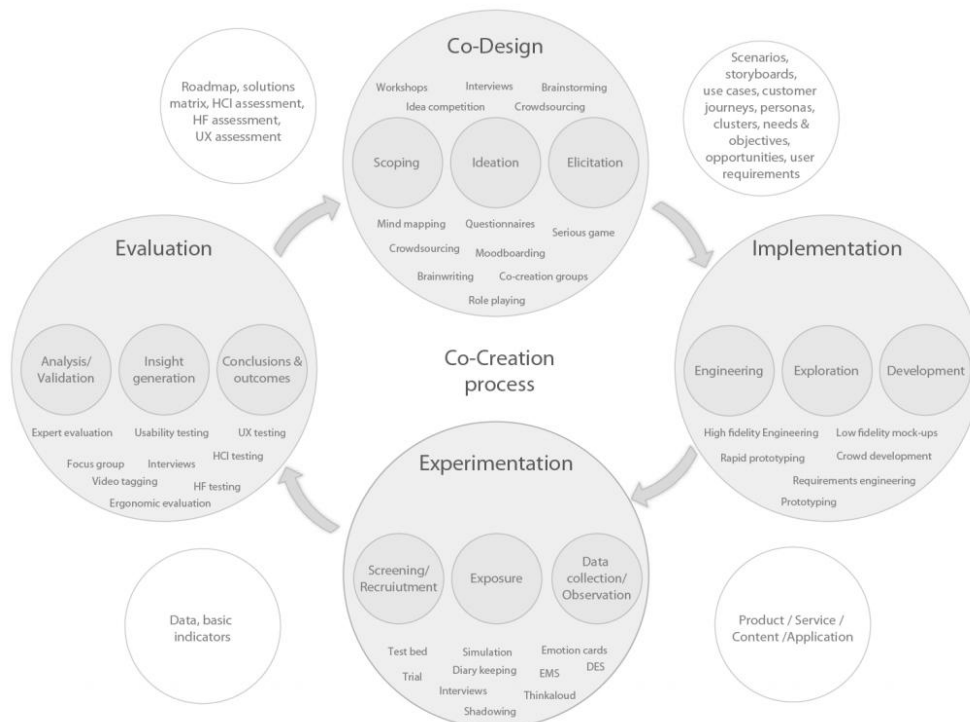


Figure 3. The Co-Creation Living Lab methodology adopted by the City of the Future Living Lab

can monitor different biological parameters (e.g., heart rate, breathing and metabolic equivalents) and share this data, along with other information, with their trainers, doctors, nutritionists and so on, in order to receive from them personalized help via both the app and the web portal. This service is integrated with individuals' PHR. The M3 information platform is also complemented by a non-clinical, educational and motivational platform whose aim is to promote active lifestyles for the general public.



Figure 4. The M3's Patch and Smartphone applications

The M3 project is currently in its evaluation phase. The project started off with a very strong and highly-technological objective: to create a working platform of an ICT-enabled and Smart service for healthcare prevention and education able to be integrated with both physiological as well as behavioral data. Thus, the co-design phase consisted of the participation in a focus group of expert users (including nutritionists, cardiologists, biomedical engineers and professional athletes) alongside a team of City of the Future researchers (including engineers and designers). Throughout this activity, the different actors were guided through a phase of analysis (with questions like "who could the service's end-user be", "what are the user requirements of this user", "in what context could the service be used on a day-to-day basis", "what other similar products and services already exist" and so on) as well as through a phase of brainstorming.

The insights gathered from the co-design phase (and which include the Engineering Awareness™ Model) were used as base for the implementation phase, where ideas and user and service requirements were translated by the City of the Future's tech team into a series of rough prototypes for the smart patch. In order to evaluate both the comfort of the patch as well as the correct flow of data from the patch through the smart device application to the platform (Fig. 5), these criteria were tested by volunteers recruited by the City of the Future Living Lab, including both sports enthusiasts as well as individuals uninterested in physical activity.



Figure 5. Moments during the M3's Implementation phase

Following the implementation phase, a more refined prototype of the service was administered to a new set of volunteers. For a period of three consecutive days, ten individuals were divided into two groups: the first who was asked to wear the patch, use the smart device application and the web platform; the second was asked to wear only the patch and not access the M3 app or portal. The reason for this was to explore the impact that viewing one's physiological data or receiving communication on behalf of a medical professional could have on the service.

Throughout the experiment, all participants were asked to keep notes of their day-to-day experiences, and, following this timeframe, they were interviewed by a researcher at the City of the Future Living Lab and asked to answer a questionnaire. Qualitative data regarding the usability and overall user experience of the entire service was then collected.

During the evaluation phase, what emerged from the questionnaires (composed of three sets of nine statements for patch, app and portal, to which each participant had to select to what extent they identified with them by selecting a number from 0-5, alongside two open-ended questions for each element of the service where participants could freely write down any comment they wanted); and interviews are a set of insights, which will be further analyzed during the evaluation phase by a set of usability experts.

For the majority of participants, the patch was described as easy to position, to wear and to charge (it received a vote above 3/5 for 9 out of 10 participants). It was also deemed easy to read and to use, though scores were slightly lower, suggesting that the patch's interface needs improvement (it received a vote above 3/5 for 8 out of 10 participants). The patch was also described as having a strong appeal since participants found it innovative, original, attractive and inviting (it received a vote above 3/5 for 9 out of 10 participants).

Nevertheless, for six out of ten participants, there were some wearability issues regarding the electrodes since, after awhile, they were described as irritating to the skin (especially for women) or beginning to peel off (especially during strenuous, sweaty physical activity) or impeding movement during physical activity.

Though all participants got used to wearing the patch (eventually, even those who wore it during physical exercise), it was much harder for them to remember to bring along the device assigned to them and upon which the M3 app was downloaded (especially for those with a tablet). As of today, the patch requires the user to have a device through which to send the collected data to the platform since it can store only a certain amount at a time.

This fact suggests that the memory of the patch would benefit from being expanded or for there to be a smaller device to be integrated into the system for the storage and passing on of data to the platform.

Instead, the app and portal were described as less usable since the language adopted was not always clear, navigation was not always intuitive and the data visualized in the form of charts was not always easy to decode and understand, and users therefore found it difficult to relate to.

For those who could access the app and portal, the service was described as being able to trigger a new awareness or consciousness of one's state of health (receiving a vote above 3/5 for five out of five participants). Individuals felt that seeing their data made them more curious about their state of health and how to improve it and preserve it throughout the day. Some said that they were going to speak to their doctors about what they had learned, wanting to understand how they could improve their state of health. One person said that participating in the experiment made her want to take up a sports activity or at least be more physically active during the day (using the stairs or walking to the closest metro station rather than taking the bus), whilst another participant who, instead, was a sports enthusiast said it made her want to perform better during training. A small minority felt that wearing the patch and having a service that stores data made them feel more looked after and secure, whilst another small minority felt that wearing the patch almost made them feel ill or different.

All participants who had access to the patch, app and portal stated that the device's pairing process with the app and the visualization of data on the portal could be improved and made more intuitive. They also suggested enriching the portal in the following ways: direct feedback from doctor or sport trainer or nutritionist; ways of tagging data so that non-biological info, such as lifestyle activities or emotional states, could be associated with it; introduce ways of cross-referencing data in a personalized manner in order to understand the whole picture better, thus making it more meaningful; possible setting ranges so that, during physical activity, the patch would vibrate or produce a sound to indicate that the individual has exceeded the desired parameters; a social network where people who like the same sports can organize training or people who work together can meet up for lunch and have a walk.

The feedback collected and the insights which are being analyzed show how important and valuable it is to involve the end-user throughout a service's innovation process. This feedback highlights improvements and modifications that can help deploy a healthcare service

that truly understands and meets the needs of the end-user. Through meaningful information and education, a drug prescription can turn into an experience able to motivate people to live a healthier, more conscientious life.

## VI. CONCLUSIONS

The overall user experience of the M3 service described in this paper by those who participated in the experimentation of the patch, the M3 app and portal was positive; more importantly, however, it has emphasized the service's high potential for improvement via a co-operative and participatory approach. The patch alone generated little appeal beyond that of the attraction to its novelty, whilst the app and portal generated more involvement, showing that a service which provides added value through meaningful information can raise awareness and conscientiousness of healthy lifestyle choices and disease prevention.

Throughout the innovation process of a smart and ICT-enabled healthcare service, the M3 project is a practical representation of the methodology adopted by the City of the Future Living, taking the co-production of healthcare services to a new level of active participation and contribution on behalf of the end user. Having a living lab through which to explore and develop a service allows researchers to have direct, unfiltered and continuous access to a vast number of users which promotes participation and produces user insights. It is just these insights that can mould a service's ability to permeate successfully everyday life because it is able to respond to real user needs as embodied by the Engineering Awareness™ model.

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