

# On Clinical, Philosophical, Ethical and Behavioural Concepts for Personalised *Insilico* Medicine Supporting “Co-production of Health”

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**Abstract.** Telemedical technology is constructed with the purpose of *compensating distance* in delivery of healthcare provisions within institutional frameworks utilizing supply-side-driven service models and ICT to "organise the delivery of healthcare". The aim of this paper is to outline "a framework of understanding" (clinical, philosophical, and ethical concepts) that uses technology to deliver personalised *insilico* medicine for use in daily demand-driven “Coproduction of Health” - and hence, *take advantage of distance* from healthcare resources and make health management of a chronic medical condition inclusive and pervasive in society; however, still founded in evidence-based medicine including use of computer-supported behavioural science models to "organise the consumption of health". Personalised *insilico* supported “Coproduction of Health” encompasses the five levers of change compiled by the high level eHealth2020 task force of the EU - #1: My data, my decisions, #2: Liberate the data, #3: Connect up everything, #4: Revolutionise health, and #5: Include everyone. The framework uses the WHO definition of health and the concept of “health capital” and introduces the “Digital Health Continuum” from 100% citizen to 100% patient and the associated ranges of "professional healthcare delivery" and "co-produced health management"- thus fusing and augmenting current supply-side driven service models with an ICT-supported and demand-side driven service model. *Insilico* personalised medicine implemented through the Coproduction of Health service-model is to be seen as a paradigmatic example of mobilizing - for the individual - all available health resources within social hubs empowered by design of innovative and collaborative frameworks to align otherwise conflicting, silo-shaped, and scattered interests.

**Keywords:** health, wellbeing, evidence-based medicine, telemedicine, prevention, non-communicable chronic diseases, NCDs, information and communication technology.

## 1 Introduction

Information and Communication Technology (ICT) for use in telemedicine has been designed to compensate for distance of a patient to institutional based healthcare.

The innovations gained in this context have been of incremental type and introduction and first implementations of such telemedical services have stimulated only minor secondary changes in organisation and business models within the healthcare sector. Seen in a societal perspective, it has been difficult to obtain reasonable cost-benefit ratios in large scale demonstrators of telemedical services when evaluated using gained Quality of Life indicators [1].

“Co-production of health” (CpH) is a coherent, compatible, complementary, augmenting, and demand-driven service-model in relation to conventional healthcare service models, where ICT is used to take advantage of distance from institutional healthcare for an active citizen with a health problem by creation of cross-sectional and -organisational ecosystems – which including also healthcare based resources. In CpH ICT is used to communicate, implement, and render operative evidence-based-medicine in societal settings and in the daily context of the individual citizen. The Co-production of Health service-model can only be real in an advanced, ubiquitous ICT-infrastructure able to recruit and exploit conventional and unconventional resources for health management.

Establishment of “integrated care” in Europe has been easier said than done probably due to the tradition in how healthcare is organised. CpH can however offer a platform for:

- Using knowledge as a tool of coordinating cross-organisational formal and informal care meaning “evidence-based, personalised, *coordinated* care and *insilico* medicine” - the European way of "integrated care".
- Support an extended corporate-social-responsibility of e.g. the food and beverage sector, meaning that commodities in the future will be sold with digital information transmitted in a format that allows for further electronic processing in relation to context and health of an individual person.
- Make knowledge on health and prevention of non-communicable chronic diseases pervasive in society.
- Support business-models based on knowledge-share principles.

This paper will not deal with the above macro-organisational issues of CpH, but describes an amalgamated, descriptive ontology for Co-production of Health with the aim of contributing to the overall framework of future design and implementation of ICT for Health and Wellbeing.

## 2 Materials and Methods

### 2.1 Creating a Framework for Understanding Health in the Context of CpH

The starting point of this work was taken in World Health Organisations definition of health from 1948, which has been unchanged since: "*Health is a state of complete*

*physical, mental and social well-being and not merely the absence of disease or infirmity*" [2]. This definition can be criticized for not being operative and for the use of the word "*complete*" in relation to three non-independent criteria: "*physical, mental and social wellbeing*". However, if instead perceived as a vision or a theoretical goal for efforts in relation to gaining personal "health capital"[3], the definition becomes rather operative. The term "health capital" was introduced in 1972 by Michael Grossman, who aimed at constructing an economic model for the commodity "good health" and the related stock of "health capital" using a "shadow price" principle that depends on many other variables besides the price of medical care. This was the introduction of welfare economics that later was continued by among others by the Nobel Prize laureate Amartya Sen [4]. Both Grossman and Sen view citizens as both consumers and producers of health and verify theoretically that the commodity "good health" has conceptual distinctions from other goods, which should be taken into account when building service models, value creation models and the associated business models.

## **2.2 Advancement in the Framework of Understanding:**

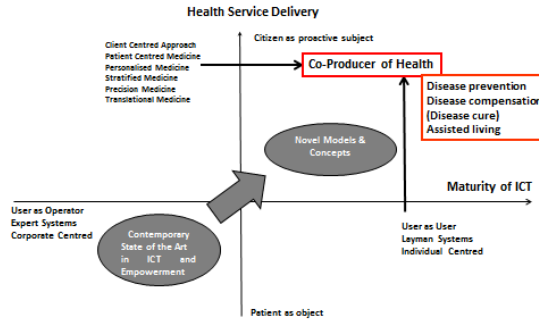
The FP-7 Support action project PREVE (FP7-ICT-2009.5.1- #248197) was a series of workshops on: "Directions for ICT Research in Disease Prevention" with selected experts receiving pre-workshop materials prepared by the project consortium<sup>1</sup>. The project-results are summarized and published in a Whitepaper [5] and serves as a part of the advancements in the framework of understanding of health reported in this paper. The behavioural aspects are based on a mutual US-EU funded workshop: "International Workshop on "New Computationally-Enabled Theoretical Models to Support Health Behavior Change and Maintenance" October 16-17, 2012 in Brussels, Belgium" [6].

## **3 Results**

Figure 1 depicts on the horizontal axis the conceptual development in ICT in the last decades, where the technology has matured from being expert-operated, corporate-centred, discrete systems to now a day's also include individual user-centred, layman-controlled, pervasive ICT-infostructures. On the vertical axis is depicted the conceptual development in medicine from the patient as a "passive patient object" receiving care to being proactive in gaining health capital. The combined development in the two domains - health and ICT - enables the new models and concepts reported in this paper.

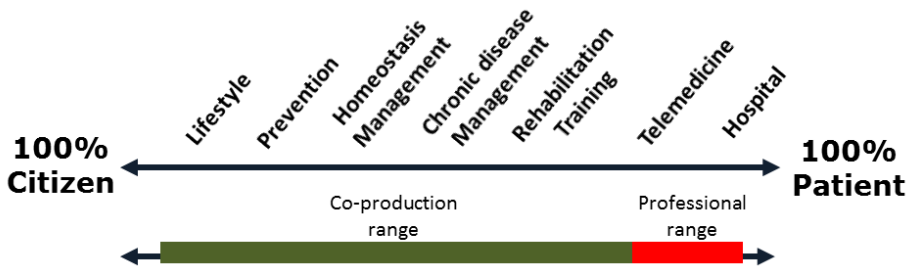
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<sup>1</sup> Consortium and core-persons in PREVE: VTT Finland – Niilo Saranummi (coordinator); San Raffaele Hospital, Milan, Italy - Alberto Sana; UPV, Valencia, Spain – Vicente Trevor, M Teresa Meneu Barreira, Aarhus University - Niels Boye.



**Fig. 1.** Disruptive innovation towards Co-production of Health is enabled by multi-axial incremental innovations

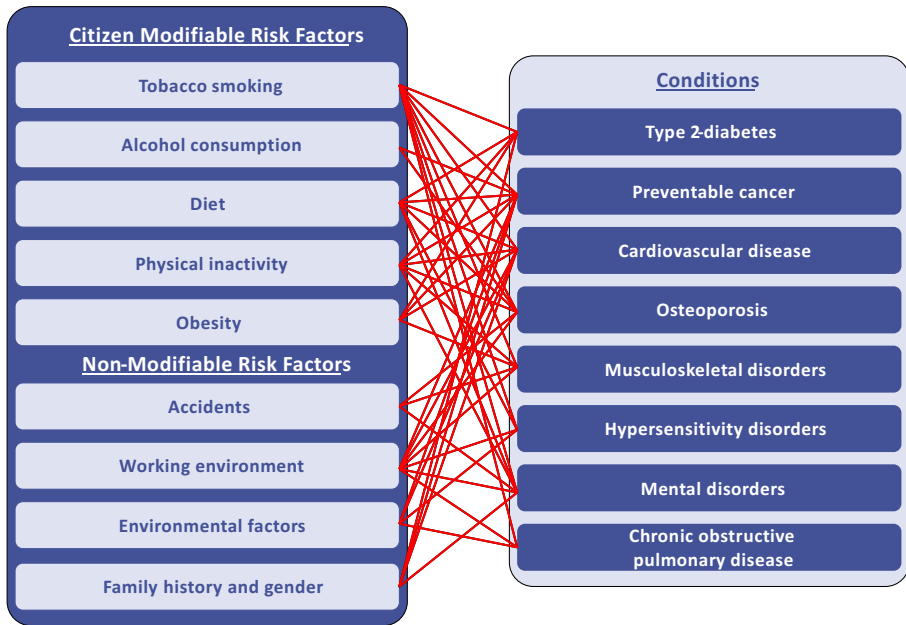
The supply side service-model of conventional healthcare has a number of components. Figure 2 depicts these supply-side model-components in relation to an arbitrary "Digital Health Continuum (DHC)" from 100% citizen to 100% patient. The provisions are divided in a professional range and in a co-production range.



**Fig. 2.** The Digital Health Continuum fuses supply-side service models (Lifestyle -> Hospital) into two demand-side service models: Co-production of Health and Healthcare professional range

The PREVE project surveyed the biomedical literature in relation to clinical impact of self-care in relation to the eight most significant and lifestyle modulated.

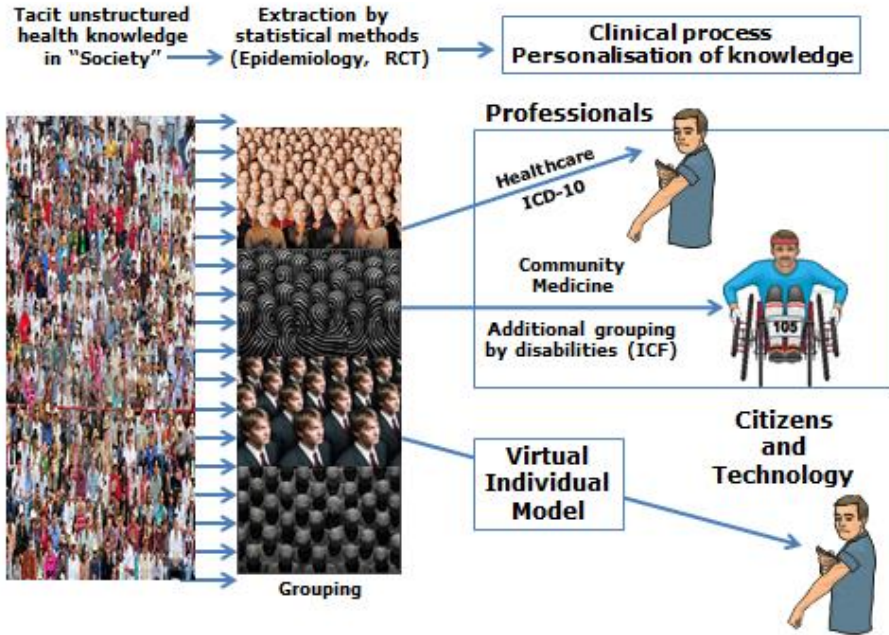
Non-communicable Chronic Diseases (NCDs). During the discussions in the expert-groups a descriptive matrix from The Danish Council for Prevention was modified and compiled into the so-called Danish Matrix Reloaded depicted on figure 3:



**Fig. 3.** The Danish Matrix Reloaded (see text for details)

Our original figure is interactive and the "evidence connections" of impact of specific self-care can be shown from single risk factors (citizen view) or from single health conditions (healthcare view); furthermore they can be combined in multiple risk factors (lifestyle view) or multiple conditions (comorbidity view). "Family history and gender" is a placeholder for genetic information.

"Personal medicine" is a vision originating in the idea of "tailor-made" drugs for the single individual. Due to regulatory and safety perspectives, it will be a vision that is difficult to accomplish for a foreseeable future. Other expressions which implies that "one size *does not* fit all" in medicine are "stratified medicine" and "precision medicine". Medical evidence is not directly based on information on individual health-trajectories, but on knowledge gained by scientific methods as depicted in figure 4 (in the left side of the figure). These statistical-based clinical and epidemiological methods imply a grouping of the participants in the trial. This grouping is defined by inclusion and exclusion criteria for participation in a trial. The highest grade of medical evidence is achieved, if a number of well-conducted trials with similar grouping by meta-analysis show matching results. In the professional conducted clinical process personalisation in relation to the single patient is done utilizing the statistically derived evidence-base containing a "non-existing average patient" with a relevant condition. The evidence is broad into action for the individual patient in the context of the single individual (right side of the figure 4) and hence tailored to that individuals' particular health problems.

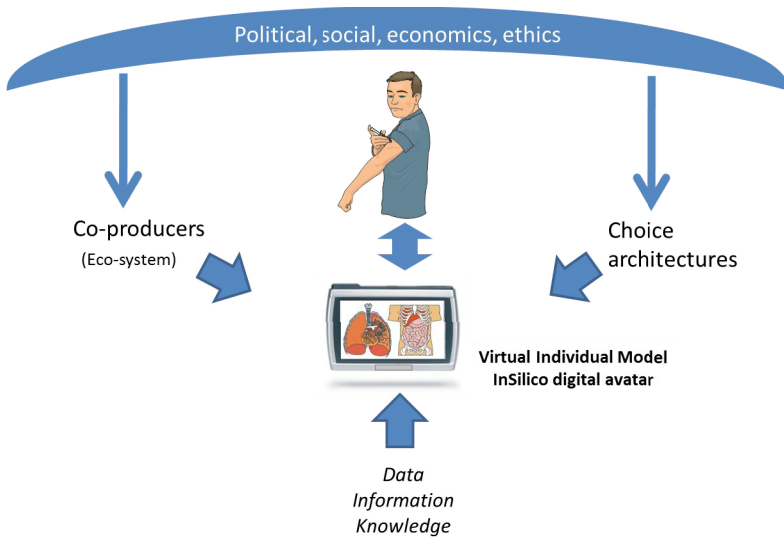


**Fig. 4.** The process of building health knowledge for evidence based medicine (left part of figure) and the process of personalizing this evidence in the clinical process (right side of figure) by healthcare professionals and by technology (virtual individual model), citizens (and professionals) in co-production of health

In co-production of health a similar mechanism is to be built using computational power and a Virtual Individual Model (VIM) that can personalise and contextualize the knowledge.

Figure 5 displays the societal boundary conditions of the Virtual Individual Model - that functions as an *insilico* digital avatar of the single individual. Choice architecture describes the way in which decisions may (and can) be influenced by how the choices are presented in order to influence the outcome [7]. Hence, the Virtual Individual Model provides personal preferences parameterization of an advanced "recommendation engine" where computational power will survey data on options, choice- possibilities and -architectures and fuse these with data from advanced sensors and furthermore, relate the information thus created to health knowledge in real time. The model with the *insilico* digital avatar in the centre is an example of "emphatic ICT-systems" that assist in bridging the gap between behavioural science theories and practical living with a chronic non-communicable disease [8].

The ethics governing our healthcare in Europe are direct descendants of the abstract principles in the Hippocratic oath with three main components: autonomy, justice and beneficence ("do good") - or at least non-maleficence ("do no harm") - in relation to the patient [9]. These abstract ethical principles are also in force in



**Fig. 5.** Co-production of health is using technology to make health management demand-driven, pervasive, and inclusive in society by supporting cross-sectional ecosystems able to recruit unconventional resources and provide personalized recommendations in context

co-production of health but the implementation is slightly different from contemporary healthcare as discussed below.

Table 1 gives a comparison of some characteristics of the two complementary methods for building health capital.

**Table 1.** High Level Characteristics of Healthcare and Coproduction of Health

<b>Health care</b>	<b>Coproduction of health</b>
Patient	Citizen
Provisions	“Good health commodities”
Reactive to disease	Proactive in relation to health
Empowerment	Responsibility and Response-ability
Closed data repositories	Open data, “big data-technologies”
Document oriented	Model driven
Classifications	System biology framework
Sector	Eco-system
Regulated marked	Open, mature marked
Institutional ethics	Universal ethics

## 4 Discussion

The WHO definition of personal health implies that there is more to personal health than receiving professional care for your diseases, although this may be an important pre-requisite in collecting health capital. The client-centred approach in medicine and the user-centred approach in ICT are both achieved by incremental innovation in knowledge and services in health and digital technologies respectively; however, when combined they can be the basis of a disruptive type of innovation able of creating novel organisation- service- and business models.

In healthcare "disruptive innovation" may not mean to put an end to what is working. It could mean creating a parallel service-model that improves some elements in the complicated machinery of care and health(care) and provide a model for how these improved elements can work with the conventional elements in institutional healthcare that do not need to be changed. The aim of the Digital Health Continuum (DHC) is to make available the framework of understanding on how the conventional and novel elements can be combined in synergy. In the professional range of DHC (hospital, clinics, and telemedicine) the ethics and regulatory instruments of professional healthcare are in force, while in the co-production range there will be a well-defined mixed responsibility and response ability between professional and lay-men resources operated on a common knowledge base.

The high-level eHealth2020 taskforce of the EU has compiled five levers for change of healthcare using Information and Communication Technology (ICT) [10]: #1 My data, my decisions, #2: Liberate the data, #3: Connect up everything, #4: Revolutionise health, and #5: Include everyone. Co-production of health is a containment of these levers and has abilities to "package" them into a coherent method or a service-model compatible with the current service-models of healthcare e.g. lifestyle management augmenting primary, secondary, and tertiary prevention of non-communicable chronic diseases. Since healthcare has a daily and very efficient, well-organised production to look after, the lever "#4 Revolutionise health" should not be perceived as making profound changes current healthcare operation, but the knowledge and data contained in healthcare should be liberated and communicated in an agreed electronic format with the aim of "organising the individuals consumption of health" with the use of behavioural science models.

The Danish Matrix Reloaded should in the context of this paper be seen qualitatively. Based on already existing medical evidence there are self-care opportunities that can be personalised according to condition, disease state of condition, and identifiable risk factors. Hence, a personal "mix" of self-, informal-, and professional-care including the use of an individualised mix of pharmaceuticals and doses are within reach as a full functioning substitute for "personalised medicine". Personalised-, stratified-, or precision-medicine requires that current and future health-knowledge can be meticulous and detailed activated. This will on the other hand demand a finer granulation in computing methods and in grouping of data in more dimensions than usual in clinical medicine. These additional dimensions must include biomarker mark-up and other molecular medicine annotations [11]. A biomarker is anything that can be used (and measured) as an indicator of a disease, a disease state, or a physiological state.



In the early stages of a chronic disease the trajectory and outcome is very susceptible to life-style management - performed in synergy with conventional treatment - since the disease process is not gone to near completion and to a clinical overt state with irreversible lesions, where only supportive therapy is possible. The advances in molecular medicine enabling the utilisation of biomarkers for early diagnosis and interception of chronic diseases will therefore prompt for alternative trajectory types to conventional institutional healthcare using ICT for pervasive knowledge handling in eco-systems, and taking advantage of distance to healthcare institutions. A positive psychology focus mainly on health and obtaining the "the good life" despite an NCD could be a side-effect of CpH.

In the industrial society "knowledge was power". Nowadays knowledge is in principle a shared resource, but often in bits and pieces and without the proper (individual) context and some of these pieces are furthermore of inferior quality. The "power" in the knowledge-society lies in the ability to fuse, filter, relate, and operationalise knowledge, whether it is derived from the internet or from scientific information obtained by scientific methods based on grouping and statistics, which can be considered distant to "personalised medicine". The Virtual Individual Model will have the purpose of combining, filtering, and relating information, and hence upgrade information to individual knowledge that can be operationalised with an impact on personal health in the WHO definitions scope; hence tailoring of the general knowledge to specific knowledge in context of the individual. The division of the Digital Health Continuum in complementary professional- and co-production range is important in relation to this. Citizen in need for healthcare should not be deprived from professional attention by a technological solution; the professional health resources will however create more impact, if in-context, personalised knowledge in "professional grade" is at hand for the citizen wishing a good and healthy life despite a chronic disease.

A prerequisite for the development of emphatic systems for personal health is an algorithmic, model-driven approach to data handling. Taking the GPS-navigation system based software and hardware as an example on a model-driven "micro-decision support system". You have the analogue problem of getting from A to B. This is converted to a digital representation of the problem and the possible solution is calculated on the basis of digital description of the appropriate geography (options and choice architectures) and the digital result is converted to an analogue display (e.g. a map). There are challenges in this. The two conversions of analogue information to data and back after the calculation must be with high validity as also the digital representation of options and choice architectures. Since a Virtual Individual Model for Health will receive much more heterogeneous input data compared to what is coming out of a GPS-satellite also the data-foundations quality, quantity, and compatibility are major challenges.

Since care was part of the Church's business-model centuries ago "care has been something that we give to each other in Europe" - in principle a societal task, that has been "tendered out" by to some extent different methods in the European countries. Complicated organisational and financial systems are built to ensure high professional standards, equal access to healthcare, an effective isolation of the patients from the true costs of healthcare, and a cost-effective operation of each link in the chain of a

healthcare process. The abstract ethical principles originating in the Hippocratic Oath are in the healthcare systems given a tangible implementation dependent of social, cultural, technical and societal conditions. The present healthcare systems are designed to respond to acute diseases and embodies concepts of autonomy, informed consent, privacy, equal access etc. which reflect these particular systems, practices, and institutions. Autonomy is typically conceived of as *a right* to reject a treatment recommended by professionals, or in general as a right to free choice. Justice is understood as any citizens' *right* to equal access to services available within the health care system. In implementing of the five levers of the EU eHealth2020 taskforce one must be careful not to confuse the abstract principles with how these principles are currently implemented in healthcare, since such confusion may lead to cyclical argumentations. ICT can contribute to an expansion in the principles of autonomy and justice and in line with history make care coproduced in society in an open, deregulated - but mature and transparent - marked. Autonomy in CpH would be a right to manage your health and get the data that is needed for this (EU taskforce eHealth2020 lever 1). Justice would in CpH be different from the current implementation in distribution-ethics of standardised healthcare provisions and will also include the complementary right to personalised *insilico* medicine with own responsibility and response-ability. Persons who take advantage of this additional right are not violating the equal access principle in the healthcare sector for professional produced provisions, on the contrary - co-production is expected to free resources and create overall additional impact.

In essence CpH will for healthcare institutions and installations mean "core-business as usual", but complemented and augmented by "an outreach" to society employing evidence-based knowledge as the coordinating mechanism in health eco-systems. *Insilico* personalised medicine implemented in the Coproduction of Health service-model is seen as a paradigmatic example of mobilizing for the individual all available health resources in social hubs with design of innovative and collaborative frameworks to align otherwise conflicting, silo-shaped, and scattered interests.

Finally, on the societal level is lifestyle because of welfare is on the brink of threatening the same welfare both in the Western and in the third world according to both OECD and WHO (see inset). Addressing

#### **Diseases that break the bank**

*"The worldwide increase of non-communicable diseases is a slow-motion disaster, ... These are the diseases that break the bank. Left unchecked, these diseases have the capacity to devour the benefits of economic gain. ... A recent World Economic Forum and Harvard University study estimates that, over the next 20 years, non-communicable diseases will cost the global economy more than US\$ 30 trillion, representing 48 percent of global GDP in 2010. ... non-communicable diseases deliver a two-punch blow to development. They cause billions of dollars in losses of national income, and they push millions of people below the poverty line, each and every year." (MARGARET CHAN, Director-General, WHO, addressing the UN General Assembly 2011)*

prevention and retardation of impacts on lifestyle related disorders on all levels in society by employing an online, distributed problem-solving production model should therefore have high priority.

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