Proceedings of the ASME 2019
International Mechanical Engineering Congress and Exposition
IMECE2019
November 11-14, 2019, Salt Lake City, UT, USA

IMECE2019-11711

INNOVATIVE PRODUCT/SERVICE FOR PERSONALIZED HEALTH MANAGEMENT

Maria Marques[1a], Fabio Lopes[a], Ruben Costa[ab], Carlos Agostinho[ab], Pedro Oliveira[b], Ricardo Jardim-Goncalves[ac]
[a]Centre of Technology and Systems, UNINOVA, 2829-516 Caparica, Portugal
[b]Knowledgebiz 2804-537 Almada, Portugal
[c]Universidade Nova de Lisboa-Faculdade de Ciências e Tecnologia, 2829-516 Caparica, Portugal

ABSTRACT

Smart4Health project is a European project aiming to empower citizens with electronic health(care) record exchange, personal connected health services, and the ability of data donorship to the scientific community. The Smart4Health platform will enable citizens to manage, collect, store, access and share own health and healthcare data, at international level, through an easy-to-use, secure, constantly accessible and portable health data and services prototype within the EU and beyond. This shall also comprise self-quantified and citizen-generated data through IoT and wearables (e.g. smart watches, smart devices/textiles/shoes). Therefore, the citizen will not only be able to access data produced in the context of health systems, but become important contributor of health data more generally speaking. The information to be collected will feed the Smart4Health platform (4HealthPlatform – 4HP), enabling the Smart4Health user portal (4HealthNavigator - 4HN) services and applications to provide advanced personalised health services accessible whenever and wherever. In this paper we explore the work being developed for data integration coming from different smart devices aiming at enriching the citizen health and personal data as well as providing insight about citizen behaviour and support on how to modify/adapt postures and habits that may contribute for better health and wellbeing.

Keywords: Digital health innovation, smart devices, data integration

1. INTRODUCTION

There is a unique opportunity for a step change, based on the wide reach of mobile networks and services, smart devices and wearables at speed: to empower EU citizen in managing own health data at the center of her/his active and healthy life in a modern digital society. The General Data Protection Regulation [1] (GDPR) and the technology convergence of digital services are key factors. 'Wellbeing services' and 'personalised (precision) medicine' are increasingly important and enabled by the power of omics approaches and personalization in the so-called Digital Health. A 2015 report [2] estimates that Digital Health could save €99 billion in healthcare costs to the EU GDP. The same report indicates that Digital Health could enable 11.2 million people with chronic conditions and 6.9 million people at risk of developing chronic conditions to extend their professional lives and improve productivity. This would add €93 billion to the EU GDP in addition.

The European Commission 2017 mid-term review of the Digital Single Market [3] lists three priorities: (i) Citizens´ secure access to electronic health records and the possibility to share it across borders and the use of e-prescriptions, (ii) Supporting data infrastructure, to advance research, disease prevention and personalised health and care in key areas including rare, infectious and complex diseases (iii) Facilitating feedback and interaction between patients and healthcare providers, to support prevention and citizen empowerment as well as quality and patient-centred care, focusing on chronic diseases and on a better understanding of the outcomes of healthcare systems.

This paper presents the Smart4Health [4] project which addresses these priorities through the development of the Smart4Health prototype comprising the 4HealthPlatform (4HP) data layer connecting with the 4HealthNavigator (4HN) portal for services and applications. Specifically, the paper presents the work being developed for data integration coming from different smart devices aiming at enriching the citizen health and personal data as well as providing insight about citizen behaviour and support on how to modify/adapt postures and habits that may contribute for better health and wellbeing.

[1] Contact author: mcm@uninova.pt

2. SMART4HEALTH CONCEPT

Smart4Health aims at developing and validating a secure cloud-based prototype for electronic health record exchange with actionable data for personalised health, that will be constantly accessible and advance it to a prototype with validated functionality and demonstrated operational use. The concept is centred around the citizen and its health-related environment. The citizen empowerment is addressed and described in so-called 'use design cases' that mirror citizens' needs, desires, preferences, norms and values around two Leitmotifs:

- I am supported in managing my own health
- I can help others by donating data

These Leitmotifs are translated by strong involvement of social-societal and humanities studies and work involving key users into designs, requirements and performance criteria, which are used for the Smart4Health prototype development with the following postulates fulfilled with the prototype:

- All citizen-centric, user-facing functions must be executable on mobile (portable) devices, such as smartphones or tablets.
- Maximum data security and privacy protection, requiring transparent communication to earn user trust

Smart4Health will empower EU Citizens with an interoperable and exchangeable European Electronic Health Record (EHR) that will allow EU citizens to be active participants in managing their own health. The key objective of Smart4Health is to place the Citizen in the centre of the decision of Citizen Health data. The citizen will be empowered with the possibility of sharing the Health Data with different Clinicians and Medical Centres, with local and international societal and Research Activities and to cooperate directly with Healthcare providers.

Through the using of the 4HealthPlatform, citizens will be empowered with electronic health(care) record exchange, personal connected health services, and the ability of data donorship to the scientific community. Activities surrounding the Smart4Health platform will enable citizen to manage, collect, access and share own health and healthcare data. Smart4Health provides an easy-to-use, secure, constantly accessible and portable health data and services prototype within the EU and beyond, thus advancing citizen health and wellbeing, nurturing digital health innovation by enhancing interoperability and bridging the gap between political intent and capability for action by the citizen. The 4HealthPlatform, will empower citizens with electronic health(care) record exchange, personal connected health services, and the ability of data donorship to the scientific community. The Smart4Health platform will enable citizens to manage, collect, store, access and share own health and healthcare data, at international level, through an easy-to-use, secure, constantly accessible and portable health data and services prototype within the EU and beyond.

The 4HealthPlatform data layer connects with the 4HealthNavigator portal for services and applications to provide advanced personalised health services accessible whenever and wherever.

Smart4Health infrastructure consist of citizen/user/data networks that are meant to become a connective tissue in the public health domain. An infrastructure is not solely a technological project, but realizes desires, values and future visions and, in doing so, always defines new relations that reshape values, practices, organisation, and forms of circulation [5][6]. An important function of data infrastructures that extend across national borders is the coordination and standardization of technical procedures, institutional actors and practices of data access, collection, protection and use. It is thus essential to reflect different values and user imaginations that get inscribed into the infrastructure and can, if not cared for, create new kinds of inequalities. Addressing human differences in contemporary societies, and in particular in the health domain is fundamental as there is clear evidence that health is unequally distributed across and within nations, and population health is often used "as a proxy for social well-being."[7] [8]

To reach these objectives and European scale, the implementation strategy behind Smart4Health is based on a truly multidisciplinary approach. The project team is constituted by eighteen beneficiaries from seven different European Union member states and the United States of America, including: ICT Developers, Hospitals, Social Sciences Researchers, Physiotherapists, Nurses, informal caregivers, Regional Government, Research Centres, Universities and SMEs. Together with the technical development of the digital platform and tools, the project will actively involve the Citizens and User Communities that will be in the front line interacting with the technology. Citizen Use Cases will be designed to include all aspects of Citizens active role in using the Smart4Health platform and to increase user experience and usability of the tool. Citizens will be able to interact and test the different steps of Health Data Management, from Data collection, storage and usage during their daily life: at home, at work, while traveling, or during leisure and sport activities.

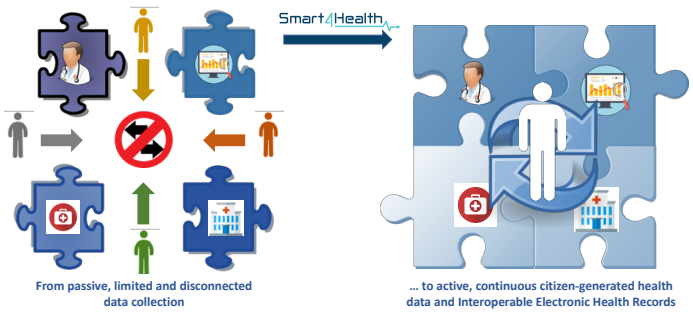

FIGURE 1: THE SMART4HEALTH PROJECT GOAL: EMPOWERING THE CITIZEN TO MANAGE OWN HEALTH DATA

The central role of the citizen is verified through the implementation of 8 different Citizen Use Cases (CUC) which were designed to include all aspects of Citizens active role in using the Smart4Health platform and to increase user experience and usability of the tool (Figure 1). Next sections detail the CUCs being implemented and specially the work being developed in the context of one of the 8 Citizen Use Cases of Smart4Health.

3. SMART4HEALTH CITIZEN USE CASES

Smart4Health implements a set of 8 different Citizen Use Cases (CUCs) for development, implementation and validation of 4HealthPlatform functionalities with the view of using a set of six different Use Designs Cases (UDCs) (see Figure 2).

The UDCs support the roles of the empowered citizens' data access, portability, control, sharing and provision. At the same time, the UDC should assure that data access is helpful for users, easy to manage, and information. The following UDCs were defined, namely:

- **UDC 1**: 'MyHealthView': Daily management – status, news, fitness cooperation. Focus on actual daily management, navigation, overview adapted for home, work, and when travelling.
- **UDC 2**: 'MyTrusted': Daily management – status. Focus on sharing information with my trusted ones - Patient Summary, Health status summary
- **UDC 3**: 'Mob.E.Health': Mobility and travel – status. Focus on sharing key information for quick understanding of status, critical information, dynamic information that is relevant in unplanned situation and/or when needing medication
- **UDC 4**: 'MyTime': Leisure, travel, fitness – status, news and journey, cooperation. Focus on actual daily management - navigation, overview, like, interesting, informative, helpful.
- **UDC 5**: 'MyWork': Occupational Health, Safety and prevention. Focus on OSH, prevention at work activities and collection of citizens generated health data.
- **UDC 6**: 'MyScience': Donation for science and research.The Citizen Use Cases (CUCs) are implemented to provide feedback to platform development, assess implemented functionalities and feed into validation.

FIGURE 2: THE SMART4HEALTH USE DESIGN CASES

The CUCs shall connect real life setting examples of enabled citizens that manage, collect, access and share own health and healthcare data. Smart4Health provides an easy-to-use, secure, constantly accessible and portable health data and services prototype access within the EU.

The Smart4Health CUCs were designed to connect real-life setting examples of enabled citizens that manage, collect, access, and share own health and healthcare date. Two of these CUCs are mainly focused on the aspects of data ingestions and data interoperability. The other six were developed around a highly prevalence health issue which was selected due to its high relevance and societal and economic implications. This problem is lumbar and/or cervical pain. In fact, lumbar pain is a condition that affects more than 60% of workers in a variety of environments [9] (from industry, to healthcare and caregiving). There is a clear association between the type of work performed and this type of pain. Typically, situations that involve long standing/sitting hours, lifting of heavy loads, etc. contribute for the development of this condition.

To this end, the six use cases were design around a combination of treatment/prevention and how these can be used in different contexts and situations. In the next sub-sections these CUCs are detailed

3.1 Citizen Use case on Back pain and Muscular-skeletal disease (MSD) treatment

The objective of this CUC is to provide the treatment therapy for approximately 1,000 Citizens. The use of 'MyHealthView', 'MyTrusted', 'Mob.E.Health', 'MyTime', "MyWork', 'MyScience' UDCs is envisaged.

The project is going to work with the MedX lumbar extension machine, which will be equipped with a set of smart sensors for collecting data on train of the deep lower muscle layers of the back. The objective of the CUC is to test the 4HealthPlatform with real data being acquired during the treatment and to decrease back pain of participants over the course of the project. Our target group will be Citizens with need of therapeutic treatment related with to back pain. The CUC will be triggered by the Citizen that suffers from backpain that seeks a Medical Doctor (MD) for treatment.

The MD will introduce the 4HealthPlatform, both the EHR service and the backpain treatment. Upon agreement on participating in the project, the MD will conduct anamnesis and prepare a therapy plan. The training and therapy sessions will be supervised by the therapist. During the treatment the citizen will be empowered with the Smart4Health applications that will allow him to manage own health data, not only during the treatment but also is a posterior phase.

3.2 Citizen Use case on Back-pain and Muscular-skeletal disease (MSD) prevention

The objective of the "Prevention of Backpain" CUC is to provide the prevention therapy for approximately 3,000 Citizens working in companies. The use of 'MyHealthView', 'MyTrusted', 'MyTime' and 'MyWork' UDCs is envisaged. Again, the MedX lumbar extension machine, equipped with a set of smart sensors for collecting data on train of the deep lower muscle layers of the back, will be used. The training will take place 18 times, once a week. The main goal is to engage participants to use the 4HealthPlatform and to make them aware of the beneficial of back pain prevention. Furthermore, the training should help to

reduce sickness leave in companies which will be beneficial for employers, as well as employees. The training will be conducted with citizens in close collaboration with the Safety and Health Office of the companies where they are working.

The CUC will be triggered by the therapist contacting the industry showcasing the project objectives and benefits to the wellbeing of the workers and value in return for the industry performance. Upon acceptance, the employer, together with the therapist, will initiate a six month period were the employees will follow the following procedure: a) Anamnesis questionnaire; b) Mobility check-up while sitting in the machine; c) Force measurement to determine the current status; c) Weekly training during four months; d) final evaluation to determine the force and mobility of lower back muscles. During the training the Citizen will be empowered with the 4Healthplatform that will allow him to manage own Health Data after the treatment.

3.3 Citizen Use case on Caregivers' workplace, back pain prevention

This CUC is performed by adapting the established conditions in the previous one, with emphasis on the needs of caregivers and nurses as workers in home care setup. The use of 'MyHealthView', 'MyTime', and "MyWork' UDCs is envisaged. It further adds the dimension of interaction of the carer as worker and citizen with the citizens that are taken care of. It enhances the relationship and amplifies possibility to reach out with the technology to citizens that are either heavily affected by back pain as caregivers workforce and on the other hand as care receiving citizens gaining a trusted access to dedicated functionalities that may add value for the citizen.

3.4 Citizen Use case on Hospital workplace, back pain prevention

The use case will involve the huge teams of the health workforce itself working at the health centres. The CUC is performed by using the tools established in the CUC presented in section 2.3, expanded to the needs of caregivers and nurses as workers in a University hospital Intensive Care Unit. The use of 'MyHealthView', 'MyTime', and "MyWork' UDCs is envisaged. It further adds the dimension of interaction of the carer as worker and citizen in the most complex and demanding occupational condition, which is known to cause high rates of inability to work due to physical and mental factors. In addition, a high technology and robot-supported environment provides additional sensor input of data that is ingested to the 4HealthPlatform. Feedback functionalities, sharing and relationship are key for the citizens in this workforce that are themselves heavily affected by back pain. Trusted cooperation, feedback and sharing can significantly add value for the citizen and for the outcome of the work performed.

3.5 Citizen Use case on Regional health, tourists, preparedness, back pain prevention

The Region of Madeira is a Portuguese island located in the Atlantic Ocean with an area of 741 km2 and a subtropical mild clime. Madeira is the second wealthiest region in Portugal and an extremely popular touristic destination, all over the year.

Being the most demanding Citizen Use Case in terms of citizen involvement, this is the use case that requires a very well designed strategy to ensure user engagement. To this end an active communication campaign is already being developed in order to raise awareness and motivate participation.

The use case focusses on a broad societal use of the platform in a region and cross-border focus is on the design use cases 'MyHealthView'. With a view to the strong role of tourism and citizens travelling to Madeira and also engaging in activity, the use design cases 'MyTime' leisure, fitness and 'Mob.E.Health' have an important role. The intention is to address the associated use situations of the citizens, citizens travelling and spending leisure time actively on Madeira with possible cooperative fitness, hiking and training activity.

The implementation of the use case will have two storylines: one focused on the tourist (i.e. someone that arrives to the island for a short stay) and another focused on the local citizen (i.e. someone that lives in Madeira).

3.5.1 Madeira Tourist storyline

The tourist arriving to Madeira will have access (at the Airport or Cruise Ship harbor gates) to information regarding the project objectives and impact in the wellbeing of EU citizens. The tourist will receive information on how to register and use the S4H application, moreover a wearable that he can use to acquire data to the platform will be provided. This initial step will empower the tourist to acquire health and fitness data that can will be securely stored in the S4H application. During the stay in Madeira the Tourist will be able to collect a variety of Health Data (depending on the used wearable). In the case the tourist requires any medical assistance or to provide fitness data, the user can use the S4H application to share the records to the MD or hospital center.

3.5.2 Madeira Citizen storyline

The Madeira Citizen working in the hospitality industry will have access to the Smart4Heaalth EHR Platform via the Health and Safety Office of the employer. The Service provided by Smart4Health to the industry partners engaged in this CUC will include: access to the Smart4Health EHR platform, wearables and to a physiotherapy back pain prevention and treatment.

The hospitality worker will be introduced to the Smart4Health objectives and impact in his wellbeing. In parallel the worker will have the opportunity to perform a physiotherapeutic test to the lumbar back muscles that will allow to improve his strength in the back-pain muscles. After the first evaluation the worker will be incorporated in a four months training to increase muscle strength (prevention) or to treat any symptoms of lower back pain (treatment). During this training, the worker training records will be stored in the Smart4Helth platform. The citizen will also have access to the Smart4Health application where he can store the data collected by provided wearables.

During and after the training period, the employee will have the possibility to share the collected data with his employers

Health and Safety Office, GP, hospital or medical center in Madeira or in any other location in Europe.

3.6 Citizen Use case on Life and workplace, back pain prevention

This CUC is performed fully similar to the previous one but with emphasis on the needs of workers in a dedicated multi-business industry parks in Portugal and Spain. As a trigger the industry worker will have a routine meeting with the Health and Safety office from the company, where the 4HealthPlatform will be introduced. The advantages of the system will be explored by the MD and access to the 4HealthPlatform, wearables and physio training will be provided. Upon agreement the worker will start using the wearables during his daily routines (at work and outside work) and, a training session with a physiotherapist that will perform an anamnesis and a mobility check-up. Upon medical analysis the worker will start the training or treatment of the lower back muscles for the next 4 months. During this period the MD and physiotherapist can support the worker by following the data from the wearable and suggest improvements on the posture in different tasks during the daily routines. This action will allow the worker a better assessment of his posture and to better engage with 4HeathPlatform. At the end of the physiotherapeutic training period the worker will be able to understand his evolution and improve the daily routines to increase quality of life.

4. IMPLEMENTATION

The implementation is being done in the context of the Citizen Use Case on Life and workplace, back pain prevention (section 3.6). At this stage we identified two wearables that will be used to collect data and derive knowledge about citizen behaviour and provide support on how to modify/adapt postures and habits that may contribute for better health and wellbeing. Our main target is in understanding the impact of long standing/sitting hours (e.g. operating a machine or working in an office). To this end we selected:

- A wristband that will be used to collect information like: heart rate, steps, distance, calories, etc.
- A Bluetooth sensor that will be used to detect if the person is standing or sitting

The wristband being used is a MiBand 2 from Xiaomi[2], powered by a 70mAh cell that offers approximately 20 days of use on a single charge.

The wearable sensor, developed in the context of SmartLife project [10], is composed by an accelerometer, a gyroscope and a magnetometer that has been designed considering the following requirements: 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer (with units of g's, º/s and uT respectively) autonomy of ± 20 hours and internal memory [11]. Figure 3 shows the internal composition and comparation in terms of size. At the same time, the sensors must be designed in a highly integrated fashion, optimizing across all levels of system abstraction, with the goal of minimizing energy dissipation.

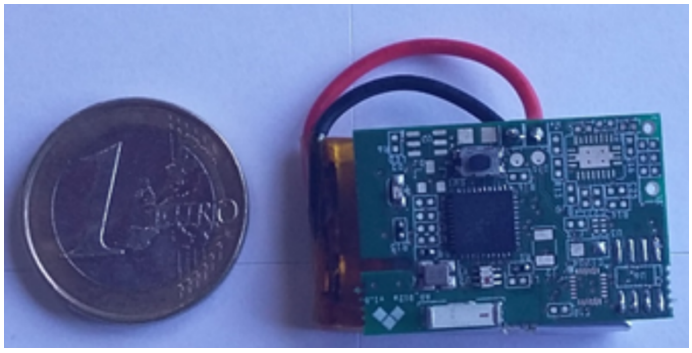

FIGURE 3: WEARABLE SENSOR

Based on the BLE standard features, the wearable Bluetooth device transmits information in 3 modes:

- Transmission (offline): Data is transmitted in the payload of the Advertisement Packet. This data includes this fields:
  - Identification data of the device.
  - Push button status.
- Notifications (with connection - online). The data is sent automatically:
  - Online values data of the 9-axis of the sensors
  - Device status data such as real mode, battery level and free memory.
  - Button status and pulse time (when button is pressed)
- Reading / Writing (with connection - online).
  - Data sending frequency (R / W)
  - Operation to be carried out (R / W)
  - Battery Value Data (R)
  - Firmware version (R)

The data collected is sent to the mobile phone of the user that acts as data integration hub. A mobile app was developed that is used to perform data analysis and visualization (Figure 4).

The testing scenario involves the detection of standing/sitting hours. The Bluetooth sensor was programmed to detect the changing in the position (from standing to sitting and vice-versa) and sends that information to the mobile phone. This way it is possible to derive the time that the user spends in a specific position. That information, together with the other parameters collected through the wristband enable to obtain insight on some specific aspects that may affect lumbar health. As an example, someone that stands for long hours in the same position and does not follow an exercise routine capable of contradicting the effects that behaviour may have, will possible experience stronger lumbar pain than someone that tries to follow an appropriate exercise routine.

[2] www.mi.com

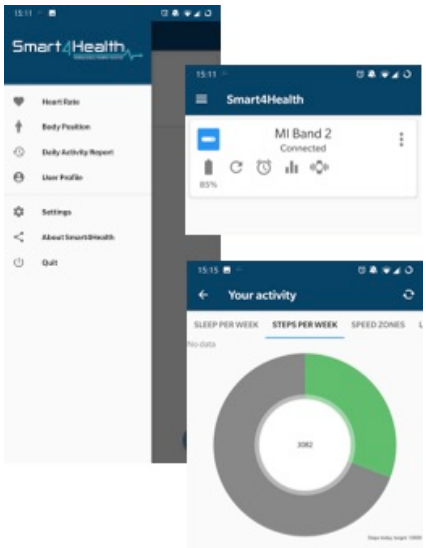

FIGURE 4: SMART4HEALTH MOBILE APP

Note that the aim of the Smart4Health app is not to disturb the daily routine of the user, and so no notifications will be issued. The main goal is to use the information collected and provide better knowledge on the effects that a specific behavior is having on the user lumbar health.

5. RESULTS AND DISCUSSION

The results obtained at the moment are purely from the technical side as the project is currently in the requirements phase and the developments made are only aiming the testing of come initial concepts. For this reason, the results here presented are still not mature enough for users starting the testing.

Currently the main achievements have been:

- The detection of changes in the user position;
- The interconnection of the two wearables in a single data integration hub;
- The visualization of the user behavior along a period of time.

The results obtained are very promising from the point of view of multi-device interconnection. Also, the integration of a multitude of data sources allow us to consider the possibility of obtaining a diversity of data, that once processed and analyzed can be used to provided valuable knowledge to the user.

In this sense, next developments will consider the inclusion of additional data sources. Specifically, the inclusion of sensors to detect if the user is lifting heavy loads and how is this activity being performed (through the addition of posture sensors). Again, the envisaged developments aim at taking the most out of the collected data in order to provide insight about how daily activities impact negatively lumbar health and what kind of mitigation measures can be implemented (by the user) to limit that impact.

6. CONCLUSION

This paper presents the work being developed in the context of Smart4health project, specifically the implementations done so far in what regards the Citizen Use Cases.

As the project started in January 2019 (and will run for 50 months) the development is still on very initial phase. At this stage the main aim is to identify data sources of interest, testing connectivity and setting the ground for more mature developments.

As the work progresses the results obtained will include insight about the efficiency of the approach, not only from the technical side (i.e. on collection and integration of data) but also from the user point of view through the provision of metrics to evaluate the impact on users health and wellbeing.

ACKNOWLEDGEMENTS

This work has been developed in the context of Smart4Health project. The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 826117.

REFERENCES

[1] Regulation (EU) 2016/679

[2] https://www.gsma.com/iot/pwc-report-realising-the-benefits-of-mobile-iot-solutions

[3] COM(2017) 228 final

[4] www.smart4health.eu

[5] Larkin, B. (2013). The Politics and Poetics of Infrastructure. Annual Review of Anthropology, 42, 1, 327-343.

[6] Slota, S.C. & Bowker, G.C. (2017). How Infrastructures Matter. In Felt, U., Fouché, R., Miller, C.A. & Smith-Doerr, L. (eds.) The Handbook of Science and Technology Studies. Fourth Edition. Cambridge, MA: MIT Press, 529-554.

[7] Nowatzki, N.R. (2012). Wealth inequality and health: a political economy perspective, Int J of Health Services, 42, 3, 403–24. Hall P.A.

[8] Lamont M. (eds.) (2009). Successful Societies: How Institutions and Culture Affect Health. New York: Cambridge University Press.

[9] https://www.ncbi.nlm.nih.gov/pubmed/22359986

[10] http://www.smartlifeproject.eu/

[11] SmartLife Consortium, "D4.1 - Data collection, cleaning and fusion services, September 2017"