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The Future of Healthcare: One Million [Interconnected] Homes Initiative

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An ageing society and global health crises have increasingly meant that people are spending more time at home than ever before. While homes are thought to be "safe" environments, people – especially those who are aged or health-compromised – face multiple dangers such as falls, cuts, burns and drowning and increasingly, mental illness stemming from loneliness and isolation. What role can emerging connected technologies such as smartphones and wearables and Ambient Assisted Living (AAL) technologies and solutions play in the future generation of home-based, patient-centred healthcare and wellness prevention and environmental sensing? Prof Henrique Martins shares his vision.

Key Points

- A healthy home is essential for a healthy life. Environmental variables such as street noise, lighting, temperature, and air quality, collectively called exposome, are directly associated with quality of sleep, work productivity, allergic disease, and even heat-related cardiorespiratory mortality.
- Healthcare is moving from hospitals to homes, and from inpatient to home-based patient care. An ageing society and global health crises have increasingly meant that people are spending more time at home than ever before.
- Emerging connected technologies (e.g., smartphones and wearables) create opportunities to understand an individual's behaviour through the lens of systems biology, often called behaviourome.
- Ambient Assisted Living (AAL) includes the technologies and solutions for smart homes, as well as smart environments and cities, and has been a topic extensively featured in EU innovation, technology development and pilot projects over recent years.
- We now need to "join the dots" and combine all of the scientific and technical conditions into EU-wide continuous seamless telemonitoring from home to home, wherever home is, to each EU citizen at any given moment.
- The proposed "One Million (Interconnected) Homes" initiative can start small – between the EC and a few interested countries, building its governance, workstreams, and producing useful deliverables and then progressively grow to eventually be supported by an EC-funded Horizon Europe project for more sustainable work.

Healthy Homes and the Exposome

A healthy home is essential for a healthy life. An immense body of evidence accumulated over many years and covering many topics shows that our environment directly influences every part of our health. As an example, low street noise, night time lighting, isolation from sound and general quietness is associated with quality of sleep, which in turn is associated with better health or several health conditions, including children's school performance and adults work productivity (Halperin 2014). The quality of the air, the dust and other exposome (or collective environmental exposures beginning during the prenatal period) are determinants related with allergic disease (Burbank et al. 2017). A single environmental variable, such as temperature can be related with death. Morais et al. (2021) showed through hot spot analysis that the neighbourhood-scale spatial pattern of

heat-related cardiorespiratory mortality in the elderly, during the yearly warmest five months of a three-year period was associated with spatial variability in heat-related mortality. They concluded that studying human health outcomes at a neighbourhood-scale is relevant for public health heat-related plans and outlined suggestions to decision-makers and city planners designing strategies to reduce heat-related mortality (Morais et al. 2021).

That healthcare is moving from hospitals to homes, and from inpatient to home-based patient care is undisputed. That people spend much more time at home than anywhere else is equally undisputed. An ageing society and global health crises have increasingly meant that people are spending more time at home than ever before in recent decades. While homes are thought to be "safe" environments, people – especially those who are aged or health-compromised – face multiple dangers such as falls, cuts, burns and drowning and increasingly there is an additional smouldering danger - loneliness.

Ambient Assisted Living Technologies

There are high expectations from telemonitoring technologies, and necessary strategy and services still need to be put in place in most EU Countries (Amorim et al. 2020). While the COVID-19 pandemic may have triggered interest in telehealth and telemonitoring, time has also shown that sustainable interventions require long term vision and strategy and a significant refactoring of the way healthcare systems have been designed. The scope for assistive technologies, however, are much larger than telemonitoring. Ambient Assisted Living (AAL), which often includes the technologies and solutions for smart homes, as well as smart environments and cities, has been a topic extensively covered by EU funding, particularly in innovation projects, technology development projects and pilots over many years. Too often, these have focused on the intersection between AAL technologies, homecare/prevention, and elderly citizens. Age and the conceptualisation of homecare as a sort of "safe harbour" for chronic patients, or elderly citizens at risk has prevented the realisation that young adults and even children can also benefit from telemonitoring, home sensing and the many benefits that AAL technological solutions can bring. Even the challenge of multiple-person sensing has often been neglected, as the most common focus for the use of homecare has been the "isolated elderly citizen living by him or herself in some remote location and requiring telecare/tele-vigilance". While it is a strong argument that this population group could benefit, there is a much stronger one that ALL population groups may benefit from AAL technologies, particularly as they transition to the new "home-health". As I explained previously, home-health will become a basis for a new sort of wherever and whenever people are where they "feel" at home.

One of the challenges with this vision, however, is that contrary to the stereotypical isolated elderly citizen or patient and are associated with much higher risk of overheating or suffering from hypothermia. Sensing temperature is hardly a technological challenge, however collective monitoring and regular communication and interpretation of the data, automatically raises a number of other technical, legal and ethical challenges.

Young adults and even children can also benefit from technological set-ups using homes not just for telemonitoring or assistive technologies but as wellness and sensing technology information hubs

Emerging Connected Technologies and the Behaviourome

Outside of the home, emerging connected technologies (e.g., smartphones and wearables) create opportunities to understand an individual's behaviour through the lens of systems biology, often called behaviourome. Multimodal high temporal resolution data derived from connected devices can be used to build digital phenotypes and/or discover digital biomarkers of the behaviourome (Rashidisabet et al. 2020).

Homes are the ideal place to sense people's health or concentrate outside home sensing so as to reconstitute the person's behaviourome avatar. They can be data hubs to collect, recollect from wearables (devices people wear during the day even when away from their home) and connect into digital health systems. The data they will gather is digital health and "microenvironmental" health-relevant data which may allow novel micro primary prevention efforts targeted at the exposome and behaviourome, as a new type of personalised-medicine public/populational health.

In the prior example of heat-related mortality, following the temperature of households at a micro level may allow public health services to fine-tune interventions for elderly and medically compromised people who are living alone

with a chronic condition in their home (e.g. suffering from severe health failure or respiratory conditions requiring home respiratory support), young adults and children, move – they move a lot. They even move to other countries, particularly EU Member states for work, study and leisure. While their right to free movement is a fundamental cornerstone to the EU raison d'etre, the benefits they enjoy from "home-health" require a somehow continuous gathering and analysis of health-related exposome and behaviourome data. This means we need to foster cross-border mobility and a digital single market for assistive technologies so that interoperability and continuous connectedness is possible, even for active, moving EU citizens.

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Legal and health imperatives exist. Fifth generation (5G) technologies, lightweight AAL wearables are increasingly available in the EU market and new models of home telemonitoring and health systems usage and even reimbursement of homecare have been piloted and extensively supported by EC funded projects. Data standards and transfer protocols have matured. We now need to "join the dots" and combine all of the scientific and technical conditions into an EU-wide capacity for continuous seamless tele-monitoring from home to home, wherever home is, to each EU citizen at any given moment. Our goal? To create an Ambient Assistive living healthy space at European scale.

One Million Homes Initiative

Under the current debate of the European Health Data Space (EHDS), in an earlier publication I have advocated for a place for social media. Here I argue that we also need health data places for data collected and provided by healthy individuals and/or from their homes. This will allow us to tailor interventions such as city planning, environmental legislation, micro-health environment surveillance and foster true assisted living which, in my opinion, need to move into assisting healthy individuals to live healthier lives. We need home health data collection communities and real-world evidence of how people interact with the environment and with each other if we are to design new medicines or digital therapeutics to fight increasingly common neurological conditions such as dementia and mental disorders while promoting mental health.

Health systems design and management is for the most part an EU member state prerogative protected and foresee in the EU Lisbon Treaties. The suggested ideas in this paper, would require such national level changes, while at the same time, the Digital Single Market, new Data Governance Act and other similar EU-wide initiatives on the free circulation of data, may serve as basis upon which to build EU-wide telemonitoring and ALL interoperable spaces. In 2020, the European Commission (EC), via DG Connect and a first set of Member States Ministers of Health launched the One Million Genomes initiative, which later led to the Beyond One Million Genomes project. This project combines EU-level responsibilities and capabilities with those at the Member States level, respecting their autonomy while creating a collective target and setting in motion a series of joint efforts to establish a "EU-Genome poll".

If we are to have an EU exposome and behaviourome while creating the largest functional and interoperable telemonitoring and AAL digital technology market, we need a "One Million Homes" initiative. Like its inspirational initiative – the One Million Genomes – it can start small – between the EC and a few interested countries, building its governance, workstreams, and producing useful deliverables and then progressively grow to eventually be supported by an EC-funded Horizon Europe project for more sustainable work. This should differ from the many "pilot projects" on telehealth or AAL in three main elements:

- **Scale –** only a very large-scale project can ensure definitions, standards and agreements create a large enough market momentum for SMEs to embrace them and to create EU-wide market players capable of being competitive outside the EU.
- **Cross-border nature –** most projects in telemonitoring or AAL have been local, institutional or national/regional implementations, even if multiple countries/institutions may have participated.
- **Data Connection –** as a "next generation" and European Health Data Space enabled initiative, it can be envisioned as one of the first large-scale health-related data donation initiatives.

Homes can also be connected between themselves in healthy virtual neighbourhoods. They should not just be "connected" to some abstract place to hold data somewhere

in the EHDS, but rather be generating useful data resources for research and innovation. Interconnected homes can establish new ways of telepresence amongst themselves, and collective tele-synchronisation of families and friends – something we learnt was essential to survive isolation during recent pandemic times. Isolation daunts many citizens, not just elder, chronic patients or those incapable of easily going outside their homes, and is responsible for several mental health conditions. Of course, loneliness, can also be felt amid a crowd. The current online social system does not address this issue. In fact emerging research shows that social media can have the opposite, detrimental effects (Marttila et al. 2021). Next generation interconnected AAL telecommunications such as sensing and other assistive telecommunications may thus be the new 6G, moving from supporting the Internet-of-Things (IoT) into supporting the Internet-of-Humans (IoH) or the Internet-of-Homes (IoH). The One Million (Interconnected) Homes initiative may be the start of this new paradigm.

Conflict of Interest

None. ■

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