5G for personalized health and ambient assisted living

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Introduction

There is an increasing awareness that healthcare in the western countries cannot be continued in the way it has developed in the past; It is just not sustainable due to the increasing demand for volume of care, limits to the amount of qualified people to work in care and limits to the amount of money we can spend on healthcare. A main trend that is contributing to this need for change, is the increased life expectancy of our western society. As the years that are added, come with longer period of time in which we have to cope with chronic conditions, the volume of required health care services is rapidly rising. This increase in volume of care needed cannot be met with a proportional increase in professional personnel and money. There is a strong belief that technology, especially information and communication technology can make a significant contribution to make care more sustainable, by supporting people in their wish for independent living and increase of self management capabilities. Areas that are especially relevant in this context are:

- Unobtrusive monitoring of health related conditions and behavior
- Home based interventions. Enabling people to do therapy like physical and cognitive training at home, remotely supervised
- Personalised Health Systems that provide people in real-time personalized advices about their health, based on multimodal sensing
- Caring homes, supportive environment that intuitively feels the needs of its user and is able to react properly

These areas are coming up fast due to rapid developments in sensing technology, artificial intelligence and improved communication infrastructures [7]. In this chapter, I would like to describe some recent developments in these areas of health care supporting technology, both from a technical and functional point of view and then, based on the present developments try to imagine how 5G will support and/or accelerate these.

Technology to support personalized health and ambient assisted living

2.1 exercising at home

When patients are able to do their training at home, this would have great benefits for all stakeholders. Patients can do their training where and what time they want, not being obliged to go e.g. three times a week to a physical therapy practice or a rehabilitation centre [8]. If it is partly replacing the intramural therapy sessions, it is also becoming more cost effective and enlarging the capacity of intramural care. If it is used as an extension of intramural rehabilitation, it will help in decreasing the fall back of capacities in the home situation.

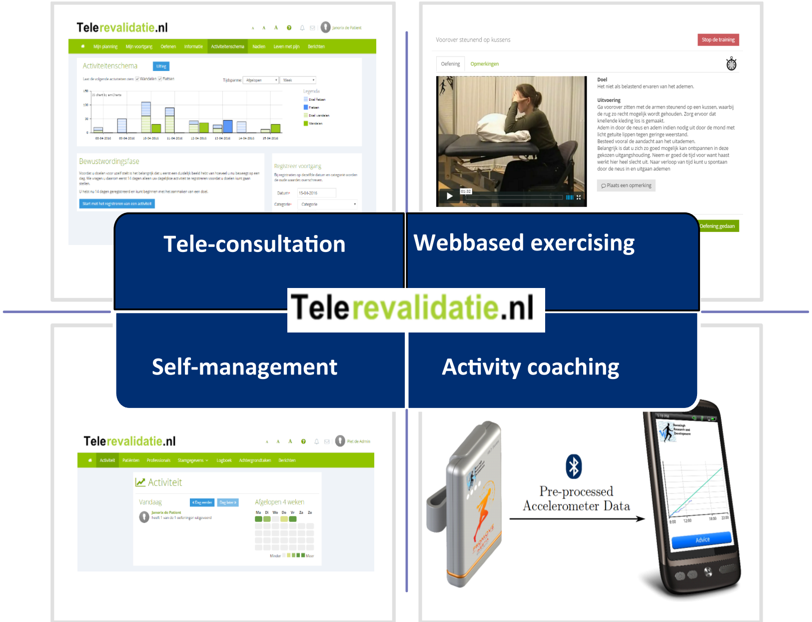

Figure 1. Example of a patient platform, supporting webbased exercising, video teleconsultation, self management and activity coaching (Continuous Care and Coaching Platform, RRD)

In the EC project Clear, in the period 2011-2013, 1000 patients in 4 European countries were using a system that was able to deliver videos of exercises, an exercise scheme, remote supervision and teleconsultation services. In the extensive health technology assessment it was shown that this remotely supervised treatment was cost effective and efficient when applied as partial replacement of the regular intramural therapy. Moreover, it was shown that the patients, who exercised more, improved more. This underlines that the patient is in the driver seat and is able to take control.
The advantage of this approach is that it is fully web based, making it independent of place and time and relatively low-tech, meaning that you only need a pc or a similar device to get the service working. As such, it is a good first step to introduce this kind of technology in daily healthcare.

A next step in the training at home involves much more complex systems involving games to make the exercises more enjoyable and persuasive, combined with passive or active robotic support systems to correct the movement and/or support the patients in carrying out the desired movement when muscle force is still not sufficient. An example of such a combined system, is the Script system [1], developed in the European Script project, targeting upper extremity training for stroke patients. It involves an arm/hand support system that allows personal adjustment of the amount of support, sensors to control the game and a number of games that vary in difficulty and a decision support system that recommends individual game setting and a choice of the games.

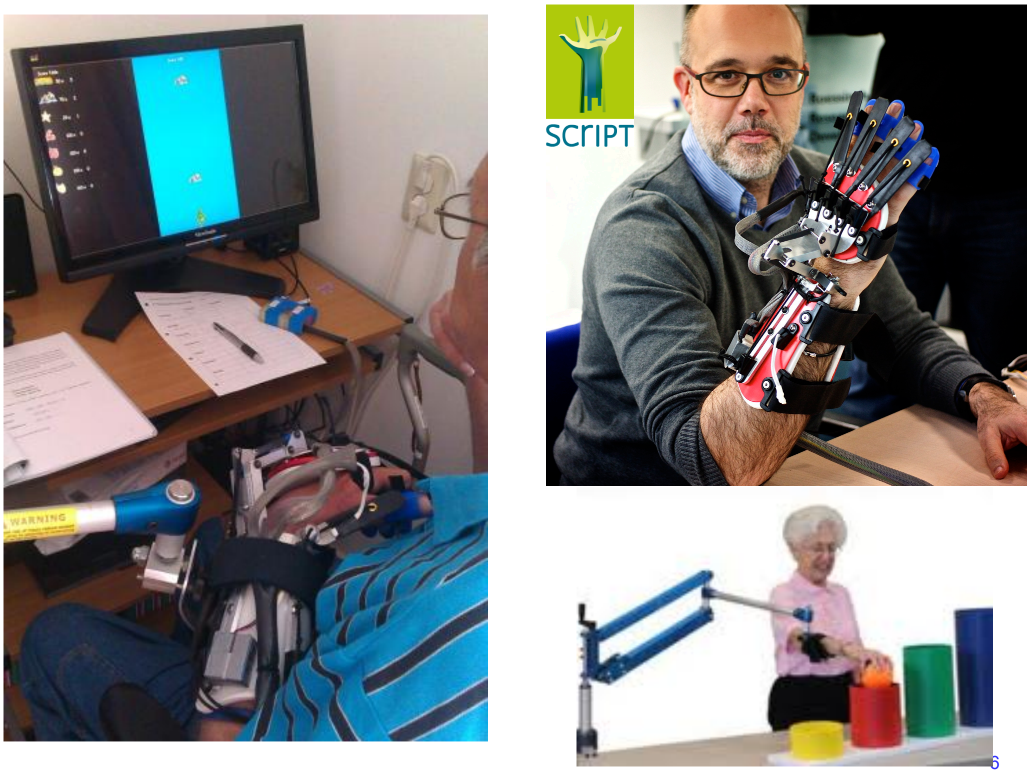

Figure 2. Upper extremity exercise system including robotic support for the hand functioning, gravity compensation and individually tailored video games (Scriptproject.eu)

With respect to required bandwidth, and technical complexity, systems like Script are much more demanding. Optimally, one would allow experienced clinicians to look at the performance of the patient exercising remotely, but also have real-time control of the robotic device as well as the virtual world where the patient is experiencing. The evaluation studies of the Script system show that such systems are promising with respect to independent and motivating exercising at home, but still rather fragile.

2.2 Movement analysis and monitoring

Movement analysis is an important step in the functional diagnosis in rehabilitation. It focuses on quantification of the movement pattern and to investigate the underlying deviations in neuromuscular control and the compensation mechanisms that occur.
Gait analysis has been restricted to laboratories, where gait was quantified using optical, marker based systems. Reflecting markers are placed at specific places on the body and assessed using video cameras placed around the subject that pulse with infrared lights to obtain a three dimensional image. Off-line these images are then combined with a three-dimensional model and force plates to

calculate joint forces. In the past years, this is being seen more and more as a so-called capacity measurement as the laboratory situation is a rather perfect environment with a very clean context, where the patient can be totally focused on the task at hand. A need has arisen to be able to have quantitative movement data from realistic situations, like at home. In the past years this has been enabled by rapid development of inertial sensor technology and processing algorithms to generate the movements from the data. A recent example of progress made in this area concerns the Interaction project.

Figure 3. The different components of the Interaction monitoring system (https://www.xsens.com/news/interaction-project/)

Here a complete movement recording and analysis system has been developed with motion sensors embedded in smart textiles, able to monitor the activities of a person in his own environment. It involves different modalities of sensing like inertial sensors to detect posture and movements, surface EMG sensors to measure muscle activation patterns and 3D force measurement under the foot. The system is presently being applied in stroke patients to monitor how they use their movement capacities in daily life, after a period of rehabilitation. The responses from both patients and clinicians are in general very positive, underlining that these kind of unobtrusive monitoring systems have great promise for future integrated care.

2.3 Personal coaching systems

The amount of people with chronic conditions is rapidly growing especially because we live substantially longer but this extension of our lives is unfortunately going hand in hand with dealing with chronic conditions that affect our quality of life. Chronic conditions cannot be cured but it has been shown in many studies that quality of life and the occurrence of co-morbidities is strongly related to the extend we behave healthy, in terms of physical activity, healthy food and avoidance of stress. We, human are not good in changing our behavior, proper and intensive coaching is essential. As we do not have the ability to do this with persons, the idea was born to do this with technical systems using on body and context sensing, smart context aware reasoning and user-friendly, persuasive interaction [6]. The concept of such Personal Coaching System (PCS) is shown in figure 4.

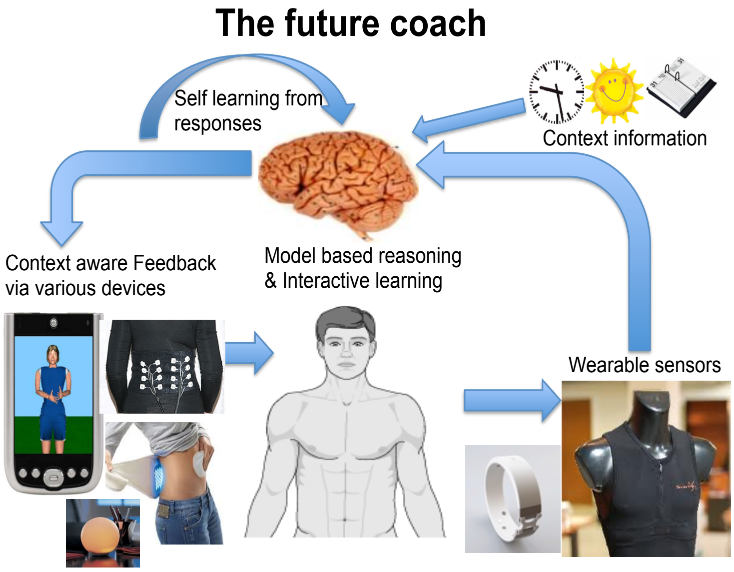

Figure 4. Schematic presentation of an artificial Personal coaching System, involving on-body sensing, context aware reasoning and persuasive feedback.

Several PCS have been realized in the past years. Figure 5 shows some examples of past and on-going work. Probably the first PCS was a system to treat neck/shoulder pain during activities of daily living [13, 14]. It involved measurement of the muscle activity in the Trapezius muscles, well known to be sensitive for stress and pain, processing the signal in terms of amount of relaxation and giving personal feedback via vibration to warn the subject when there is not sufficient relaxation. This system was successfully evaluated in a European trial, showing the system can be applied in neck/shoulder pain patients, without affecting their activities of daily living [9, 12].
A second system is a smart activity coach, developed to coach people with chronic conditions towards a more healthy activity pattern through the day. This often concerns a higher level of activity but also in many cases better balancing the amount of activity over the day, to avoid a too early exhaustion. It measures the amount of activity during the day, using a 3D inertial sensor. This measurement is continuously compared with a desired activity pattern and based on the result it provides encouraging, discouraging or neutral messages. Both the content and timing of the messages are dynamically personalized, using a model which takes into account many activity variables and context information [2,3]. The system is under continuous development but in parallel, it has been successfully applied in over 100 patients with different chronic conditions, like chronic pain and COPD [10, 11].
The third example is a stress management system [15, 16]. Stress appears to be a complex, not well-defined phenomenon. People also respond in different ways to

stress, which makes that for a PCS a personal set of sensors are required and a personalized model that is able to weight the different inputs into one estimate of stress. Experimental studies in the lab show that this approach is feasible. Experiments in free-living conditions show that a great amount of context information has to be taken into account to provide a good real-time stress estimate and to enable a proper interpretation.

Figure 5. Three examples of Personal Coaching systems, that use sensor and context information to reason about a health condition in order to provide personalized and persuasive feedback.

2.4 The caring home; supportive home environments

In order to enable people to live as long as possible in their own environment, there is a need for intelligent support systems. Ideally, the system should "feel" the needs of the user intuitively and able to react when required. In addition it is important that the system is personalized and able to offer a wide range of services in the area of health, well-being and comfort.
Presently, many projects are going on in this area dealing with several sub goals in the context of the caring home. For example Projects that aim to determine the behavior of the person using different modalities of sensing. Key target population here is people with MCI or dementia as there is a great and rapidly growing need to supervise them as long as they live in their own houses.
A good example of an overall approach to this challenge is the eWall project. The concept of eWall is to offer services in a user-friendly way using a large interactive screen, run in a browser and supported by an extensive cloud service infrastructure. The way the services are presented is innovative by using a 50's home room environment. It offers a personalized set of services including health services like an activity coach, video based exercising, a sleep qualification system and a personalized guidance through the day.

Figure 6. An integrated caring home environment, offering health, wellness and safety services to people with chronic conditions (http://ewallproject.eu/)

Integrated approaches, like eWall, require considerable bandwidth for these services as there is lot of sensing, real-time data processing and human computer interaction with animations. It is generally expected that such approach with an integration of services and using a cloud-based infrastructure will become common soon.

Opportunities due to 5G

Overlooking the described upcoming areas that will have impact on the healthcare, especially the care for people with chronic conditions, on the on hand and trying to understand and forecast the contribution 5G can have to these areas, one could make the following predictions.

Movement analysis and monitoring

For monitoring purposes, especially in the area of the analysis of functional movements, more and more rather complex multimodal sensors are used, like combinations of gyroscopes, accelerometers, magnetometers and ultrasound to get a complete 3D picture of the subject and his movements.
When these are combined with EMG measurements of several muscles, a considerable bandwidth is required. 5G would allow such simultaneous measurements in a free condition outside the lab. And probably also beyond the present set of measurements, like addition of EEG to assess motor control and mood in real-time would become possible, making a holistic monitoring of all relevant health and behaviour aspects possible.
At the other side, the viewing of all these sensor data in an understandable and comprehensive way, is a considerable challenge, especially when the data set is expanded extensively. An upcoming technical opportunity is the use of

holographic projections. This would allow the presentation of the data to the care professional in a way he/she is used to, like in his daily practice. Seeing the subject move, while information is added like in enhanced reality. The 5G bandwidth would have a big impact in making this feasible.

Personal coaching systems

Personal coaching systems are attracting more and more attention as the way forward to support people in changing their behaviour. A near real-time response of the PCS is essential, as the user has to be able to link his behaviour to the recommendations the system is providing, so he is able to be aware of his behavior and able to change it directly. More complex PCS like one for stress do require an individually modeled combination of several sensors to get an estimate of stress for feedback. The capacities of 5G would support real-time data collection and processing centrally, enabling the use of complex behavior modeling.

The caring home

The caring home is just at the beginning of its time. The upcoming Internet of things (IoT) will extend the sensing and interaction capabilities of the home environment considerably and 5G will enable real-time data collection of all the on-body and contextual IoT data, enabling a better intuitive identification of the user needs and required responses of the home environment. It will also enable the incorporation of new sensing methods that involve more data; like mood detection using real-time video processing.

Discussion

Healthcare is slowly becoming aware of both the need to change and the potential benefits of e-health and telemedicine services. There is also an increasing awareness of the determinants of successful implementation [4, 5], based on the many experiences gained in the past decade.

Present healthcare is not yet fully exploiting the capacity of the present 3G and 4G networks. Electronic patient records do use a limited amount of traffic and, apart from the imaging data, involve small amounts of data. Only rehabilitation exercising at home where videos are used to enable independent exercising does require some substantial bandwidth. Nevertheless, it is expected that this will change the upcoming years, now that many health care institutes have their EPD ready and are now looking for technology supported innovations of their care services. And this will mean that the described areas will receive increasing attention. It is expected that 5G will enable significant steps forward in the areas. The expected large bandwidth combined with high reliability and availability, will enable real-time data collection from large amount of sensors (on body, IoT), the use of complex user modeling and new ways of user interaction. It will also increase trust in these areas both by the end-users and care professional community, speeding up the large scale deployment of these care supporting solutions.

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