

Home Hospital e-Health Centers for Barrier-Free and Cross-Border Telemedicine

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Abstract The goal of the presented project is to develop the concept of home e-health centers for barrier-free and cross-border telemedicine. AAL technologies are already present on the market but there is still a gap to close until they can be used for ordinary patient needs. The general idea needs to be accompanied by new services, which should be brought together in order to provide a full coverage of service for the users. *Sleep* and *stress* were chosen as predominant diseases for a detailed study within this project because of their widespread influence in the population. The executed scientific study of available home devices analyzing sleep has provided the necessary to select appropriate devices. The first choice for the project implementation is the device EMFIT QS+. This equipment provides a part of a complete system that a home telemedical hospital can provide at a level of precision and communication with internal and/or external health services.

28.1 Motivation

Some of the AAL technologies for healthcare services have been around for a long time and yet they have barely made it into patients' homes. Some of the barriers are technological and are based on the lack of integration of data from devices (including

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heart rate, heart signals, blood oxygen saturation, respiration, muscle movement, temperature, falls, sleep patterns, etc.). They usually offer only isolated solutions. There would be a lot of potential through integrated use of the data, which is hardly taking place at the moment. The challenges posed by data protection are very special for the health sector. On the one hand, the cross-border legal situations but on the other hand the sensitivity and acceptance of the patients should be considered. Quite often, current devices and systems do not sufficiently consider the aspects of usability (both in terms of usability and user experience). These systems require an intuitive concept of use, which often affects not only the patients, but also their social environment, or even the (informal) caregivers and nurses, patient groups or other social groups.

A Home Hospital concentrates on some health areas that can be implemented domestically through AAL approaches. Stress (or stressfulness) and sleep (problems) are the initial phenomena or action challenges. In the context of intervention, we look for possibilities in the context of rehabilitation. The topic of stress is perceived by up to 30% of the population as an extreme burden (more than half feel stress as a burden). Stress leads to a variety of chronic diseases or it is predominantly prevalent in many cases [1]. Almost half of the sleep disorders are stress related, some of them are already chronic and just under half of the population has the subjective feeling of having a healthy sleep [2]. Moreover, it is assumed that 100 million people are living with undiagnosed sleep apnea, which could be quite easily detected in a home installation for sleep monitoring [3]. Different techniques of rehabilitation can be used preventively or therapeutically and thus increase personal quality of life. This effect can, in turn, be fed back by measuring stress and sleep parameters.

Sustainable health services should be comprehensive and accompany the patient or user throughout the cycle: consulting, planning, implementation, operation and support. Such services are always offered by persons and carried out with the help of AAL technologies. Sustainability is strongly influenced by user acceptance but also by economic implementation and cost models. As a particular challenge in close-border regions like at Lake Constance (Germany, Austria, and Switzerland), companies can offer cross-border health services (especially within the European Union), or it is also possible for older people to live abroad.

28.2 Relevance of Implementation

28.2.1 Rural and Cross-Border

The rural structure of the Lake Constance residents is characterized by a gradually increasing proportion of elder people, who need more support through the normal life process alone. In the region around Lindau (Germany), around 35% of the population is over 64 years old, in the Swiss cantons more elder people will live there than younger for the first time in 2020 and even in the so-called “young region” in Vorarlberg (Austria) the proportion of elder people is rising rapidly [4]. In addition, there is

an influx of people from outside who would like to settle in the Lake Constance region in the retirement age, as the region can score points due to many attractive location factors. The population growth between 2000 and 2014 was 11% and now reaches almost 4 million people living in the region [5]. By focusing the project on the main topics of rehabilitation and stress as well as sleep, aspects are investigated which are demonstrably harmful to health in the long term (stress), which affect and influence the recovery phases (sleep) of humans; rehabilitation can act as a positive control factor. At the same time, the main topics are interdependent so that their mutual effects can be investigated. The approach can be applied equally to healthy, selectively ill and chronically ill people. Thus, the selection of the group is hardly limited. At the same time, it can be seen that assistance systems are increasingly being used in private homes. On the one hand, this is due to the developments in the AAL area, but it is even more strongly promoted by the persons themselves, who would like to do more for their health or would like to maintain or increase high quality of life with their illness. Various economic incentives are already being offered by health insurance companies, e.g. when sports are regularly practiced. Not least in view of the aging of the population in important segments of the Lake Constance region, the prioritization of domestic instead of inpatient forms of living and care and the health location of private households plays an additional very important role—which has progressed very differently in the Lake Constance countries and has very different infrastructural, cultural–social demographic and political framework conditions. On the one hand, this results in particularly strong challenges for action and, on the other hand, very direct opportunities for learning in international comparison. However, the nationwide provision of assistive technologies can only be ensured if different service providers work together and the service is embedded in the overall system of a region or a country. A sustainable approach can only be achieved if these factors are brought together. Individual feasibility studies have no sustainability and are not pursued here.

28.2.2 Expected Benefit

The added value for the Lake Constance region lies in the development and testing of a service for the long-term monitoring and prevention in domestic environments adapted to local conditions is adapted to the population structure and takes cross-border aspects into account. These aspects will be considered within the framework of the project in a focused way, but they are expandable and adaptable to local needs. Each location can be individually adapted to its needs, which uses the results obtained. This is, of course, also possible over the duration of the project. The participating practice partners will perform this task within the scope of its business activities. For the scientific partners, there are opportunities for cooperation and spin-offs, which have to the core results of studies and practical elements. Scientific cooperation across national borders has existed for some time. In the project, both existing cooperation relations of individual universities/institutes are further consolidated, on the other

hand, they will be offered to other partners in the project in a new consortium composition. Attractively reinforced, this also has an effect on the possibility of offering attractive topics, which can lead to new research or even researchers in the region. The location factor of the provision in old age is becoming increasingly relevant and is in line with the following on the priority health objective “Active for healthy ageing” in the light of demographic change and socio-political relevance. This is in line with the results of the study of the Ministry of Social Affairs in Baden-Württemberg [6] and lies clearly on the line of the WHO report on healthy aging [7]. The project also identifies network barriers that actually exist across national borders and attempts to identify solutions that demonstrate the establishment of cross-border solutions. This sustainably strengthens the region and the service providers by creating new jobs in the region. With more than 20 rehabilitation clinics in the Lake Constance region, this project promotes cooperation between them. Aftercare and tertiary prevention are being simplified via this project.

28.3 Home Hospital

28.3.1 General Approach

As part of the IBH-Living Lab AAL,¹ the project—Home Health Living Lab—aims to develop a guideline for sustainable home health services. This goal is achieved in four phases: The first phase aims to identify barriers and develop a requirements analysis. The second phase aims to design the HHLLs and to identify test dwellings in parallel. The aim of the third phase is to realize a prototypical technical implementation and to evaluate the operation in the test apartments. The aim of the final phase is to refine the operation according to the first results to evaluate it neutrally in practice and to derive the sustainable concept.

Figure 28.1 shows the three work packages: (1) platforms and barriers, (2) health services, and (3) health living labs as well as sustainability. The supporting pillars are embedded in the overall structure of the individual living space (e.g., house/flat) but are not isolated from sustainable external services. At its core, the project aims at the need for assistance that is needed or desired selectively or in the long term in the domestic environment. It does not assume that illness is the trigger, since an active health-conscious lifestyle is a just as good reason. The target group is people who live in the Lake Constance region or have their place of residence, in order to sustainably secure their living situation and quality, and how to produce it or adapt it to their personal needs.

In the Home Health Living Labs, health areas are selected which can be implemented at home using AAL approaches: stress (or stress load), sleep (problems) and rehabilitation. By focusing on these main areas, several aspects are investigated,

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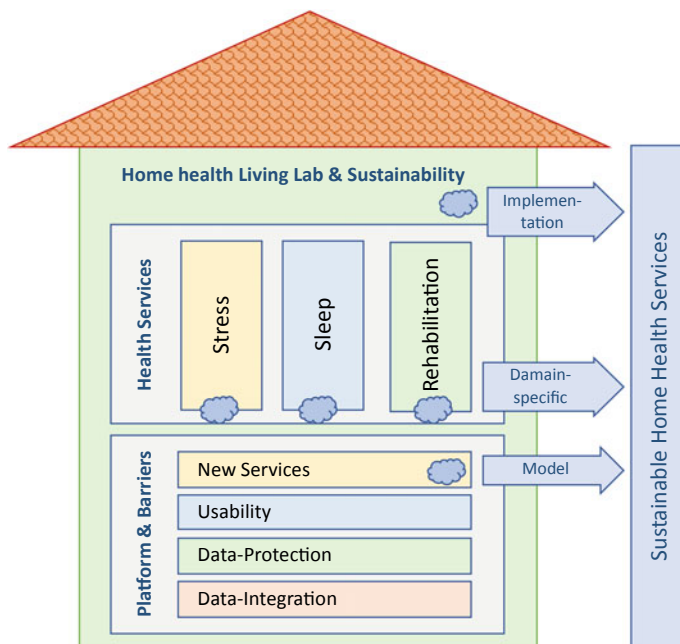


Fig. 28.1 Home hospital

which are demonstrably harmful to health in the long term (stress), which affect and influence the recovery phases (sleep) of the human being; rehabilitation can act as a positive control factor. At the same time, these main areas are interdependent so that their mutual effects can be investigated. The approach can be applied equally to healthy, selectively ill and chronically ill patients. Thus, the selection of the group is hardly limited.

Not least in view of the aging of the population in important segments, the prioritization of domestic instead of inpatient forms of living and care and the health location of private households plays an additional very important role—which has progressed very differently in the countries around the Lake Constance and has very different infrastructural, cultural-social-demographic and political framework conditions. On the one hand, this creates strong challenges for action and, on the other hand, very direct opportunities for learning in international comparison.

28.3.2 Sleep Hospital in the Home Environment

The traditional sleep study takes place in sleep laboratories. The gold standard for this procedure is Polysomnography (PSG) [8], which is a time-consuming and expensive procedure [9, 10]. Furthermore, the high involvement of medical staff during and

after the measurements is unavoidable. Sleeping in a sleep laboratory is unfamiliar for the patients and it can affect the sleep behavior [11]. However, there are some products for home environments available on the market. Because of the lack of scientific studies with detailed analysis of these devices, the selection of suitable for the described project equipment was based on published characteristics. For that, the feature matrix for the available on the market devices was created and each of them was analyzed according to the selection criteria presented in the mentioned above matrix. Some important features were determined as important criteria for the executed study:

- Price
- Measurement of heart rate
- Measurement of breathing
- HRV measurement
- Classification of sleep stages
- Movement recognition
- Snoring detection
- Availability of API

A reduced study was executed to get a reasonable selection of suitable devices. The results of the comparison study are presented in the section “Results and Outlook”. Additionally, to already presented on the consumer market devices, there are several scientific research ongoing that investigates on hardware and software parts of sleep study systems in a home environment [12, 13]. However, the current state of this research does not permit to use them in fully functional systems for end-users. Nevertheless, these works should be followed for a possible future integration in a system, developed in line of this article.

28.4 Discussion

The main objective of the project is the identification, description and reduction of barriers resulting from the integration and application of assistive technologies in the focus on health. Scientific and practice partners try to evaluate scenarios, which will be evaluated in order to obtain practice-relevant barrier-related results, which, on the one hand, provide new insights, and on the other hand, provide application-relevant results, which are of high interest for a regional implementation.

Table 28.1 presents the results of the study for the device selection in the domain of sleep study suited for the home environment. Eight tested devices have different features (e.g., recognition of heart rate, sleep stages, availability of API, etc.). All these devices are listed in the table in the first column, the next column displays the market price. The following seven columns present the main features, whereas “+” means that this feature is available for the device from the same row. Column “Extras” indicates the presence of further “not main” features and “Communication” the available communication interfaces.

Table 28.1 Results of device selection study

No.	Device	Price (€)	Heartrate	Breatthing	HRV	Sleep stages	Movement	Snore	API	Extras	Communication
1	Nokia Sleep/Withings	100	+			+		+	+	IFTT integration. Sleep Score	WiFi (BT for installation). iOS, Android
2	HugOne Sleep Sensor	55				+				Monitors temperature, humidity, and indoor air quality. Smart alarm. Smart Home integration (IFTT, Alexa, HUE, NEST). Possibly development is not active anymore!	WiFi. iOS, Android
3	Beurer—Schlafsensor—SE 80 SleepExpert	130	+	+		+	+			Smart alarm. Tips for better sleep. Export-function	BLE. iOS, Android
4	Beurer—Schmarchstopper—SL 70	100						+		On ear mounting. Rechargeable battery. Acoustic or vibration reaction on snoring	BLE. iOS, Android
5	Emfit QS HRV Sleep Monitor	320	+	+	+	+	+	+	+	RMSSD (Stress level). Recovery. There are publications on snore-topic	WiFi/mobile internet. Web-app

(continued)

Table 28.1 (continued)

No.	Device	Price (€)	Heartrate	Breathing	HRV	Sleep stages	Movement	Snore	API	Extras	Communication
6	Fitbit Charge 2	120	+			+	+		+	Quiet alarm. Tracking during the day. Up to 5 days battery life	BLE, iOS, Android, PC
7	Medisana SC 800 Sleepspace Schlafmonitor	145	+	+			+			Sleep-deepness. Sleep duration. Akku. Smart alarm	iOS, Android, Bluetooth
8	Newgen medicals Schlafphasenwecker	25				+	+			Battery (no cable). Smart alarm. Sleep duration	iOS, Android, Bluetooth
9	Beddit	150	+	+		+	+			Measures environment light, temperature, humidity and noise. Smart alarm. Export function? Not clear situation after being bought by Apple	iOS device, Bluetooth

Finally, the device EMFIT QS+ was chosen for the further field tests in line with the described project. The main reason for this decision is the availability of the following important features:

- Available API;
- Recording of heart rate, breathing and movement;
- Analyzing the sleep stages (WAKE/LIGHT/DEEP/REM);
- Calculation of HRV and RMSSD;
- Recognition of staying in bed/leaving the bed.

Other studied devices provide features, which were not regarded as optimal with respect to the specified selection criteria. Especially, the absence of an API, which was the case for the majority of tested devices, stops us from selecting them, because it is impossible to embed them into the communication environment of the planned system.

In addition to an isolated device study, the requirements for the test environments (living labs) form the part of the decision process:

- WiFi with Internet access;
- the bed with a foam or spring mattress not thicker than 20 cm and space and the possibility to place the sleep analyzer under the mattress;
- connection to the power plug not more than 1 m away from the headboard of the bed.

28.5 Outlook

The added value for the Lake Constance region lies in the development and testing of a service for long-term monitoring and prevention in domestic environments that is adapted to local conditions and takes cross-border aspects into account. These aspects will be focused within the project IBH-Lab HHLL (ABH066), but it has to consider scalable and adaptable to local needs. In the future, partners (even located in different countries) may advance in an extension that is driven individually and demand oriented, but it can benefit from the results obtained here. This is, of course, possible and desired already over the duration of the project. The practice partners involved can expand this task within the framework of their business activities (like professional caregiving service or other more convenient-oriented services).

Through the Living Lab, the long-term goal of a personalized assistance technology for health applications can be defined and transformed into products and services. This will strengthen the region through high-quality and future-oriented offers and the population spending their life around Lake Constance.

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