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Designing a Vital Data Transmission in Rural Areas with Elderly Persons in Nursing Homes and at Home

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Abstract. In this paper, we present a vital data transmission system, which aims to support general practitioners (GPs) in the process of digital vital data acquisition. The system consists of (1) an app that displays the GP's prescribed vital signs and transmits the data recorded via medically certified devices to a medically certified cloud, and (2) a web interface through which the physician can create prescriptions and view vital signs. In addition, it provides further services such as a support functionality for patients and getting feedback from physicians on vital signs. It facilitates the GPs' work, as vital signs can be clearly displayed and classified immediately in digital form. Our study examines the acceptance of such a system by GPs and patients, but also other stakeholders such as the staff of a nursing home. We therefore conducted two long-term studies in which we uncover first insights about the issues of physician underuse in rural areas.

1 Introduction

Telemedicine has been extensively researched in various fields, offering promising applications in healthcare (El-Rashidy et al., 2021; Farias et al., 2020).

One notable example is the implementation of a telemedical system in Australia back in 2006. Due to geographical limitations, certain hospitals lacked specialized doctors, requiring patient transfers to regional centers. To address this issue, a system was developed to connect remote doctors with hospital teams through video and audio connections. Clinical parameters from surveillance monitors were also transmitted, and efforts were made to adapt the system to the needs of medical staff (Li et al., 2006).

This approach of remote guidance can be extended beyond emergency services to general medicine, especially in rural areas where access to physicians is usually limited. By connecting patients with their general practitioners, telemedicine bridges the gap and might reduce the workload on GPs (Martín-Lesende et al., 2017). Studies explored the impact of telemedicine on emergency department admissions, highlighting its potential to alleviate healthcare burdens (Zachrison et al., 2020). Denmark has been at the forefront of telemedicine implementation, particularly in diabetes care (Nøhr et al., 2015). A telemedicine system was developed to support patients at home, enabling video conferencing between trained nurses and diabetes experts. User-friendliness was a crucial consideration, leading to the use of more accessible videophones instead of laptops. However, challenges arose in terms of coordinating the timing of patient-nurse-doctor interactions (Sekhon et al., 2021). The target group of patients is mostly elderly patients, who place special demands on the systems (Harrington et al., 2018). Kanis et al. (2013) conducted real-life experiments in which they explored how sensors installed in the homes of elderly individuals helped them live alone for longer without assistance. This sensor network facilitated activity monitoring and potentially led to positive health outcomes (Kanis et al., 2013).

Mobile health data collection by patients offers opportunities to support their rehabilitation journeys. The objective is to automatically record vital data without requiring manual input from users, aligning with the principles of ubiquitous computing (Kjeldskov & Skov, 2007; Weiser, 1999). While this approach aims for seamless data collection, studies often still require additional user input. Economic considerations also factor into remote patient monitoring, making cost-effectiveness a significant aspect (De Guzman et al., 2022). Due to the close involvement of patients, especially older ones, in the measurement process, it is important to include them in the design processes (Clemensen et al., 2007; Duque et al., 2019; Randall et al., 2018; Righi et al., 2017; Vaziri et al., 2019).

In summary, telemedicine continues to be a focus of research and development, aiming to enhance healthcare delivery, increase accessibility, and improve patient outcomes through remote monitoring and assistance. In our paper we want to investigate how digital vital data transmission can be integrated into the everyday life of physicians, patients and caregivers, especially in rural areas.

2 Project Overview

Our study is part of a larger research project. Within the project, the consortium established a comprehensive framework for data-driven medicine aimed at alleviating the strain on healthcare provision. A key focus was directed towards rural areas, which present unique challenges due to a myriad of factors such as an aging population and inadequate access to medical services.

The primary goal of the project entailed the development of a robust, cross-sector approach to data medicine, necessitating the resolution of various challenges across multiple domains. Central to this objective was the acquisition and analysis of vital data, coupled with its seamless transmission to a secure cloud-based infrastructure. Moreover, a pivotal aspect involved engaging patients in the data evaluation process, fostering a collaborative approach towards healthcare management. Specifically, the project aimed to explore the methods for capturing and transmitting vital data to primary care physicians, thereby empowering them with actionable insights. Concurrently, the project sought to gauge the acceptance and usability of the implemented solution among all relevant stakeholders. It is important to note that certain complex elements, such as leveraging artificial intelligence for data analysis or integrating with existing telematics infrastructure, were deemed beyond the current project's scope and feasibility (Keil et al., 2022a).

The project's conceptual framework exhibited noteworthy features from diverse perspectives. The chosen region exemplified the characteristics of a rural setting, encompassing three localities in Germany. A macro-level analysis of the region's surrounding communities revealed an imminent threat of physician shortages, further underscoring the significance of the project's focus. Given the sensitive nature of medical data processing and storage, stringent security measures were imperative. The data protected under the stringent regulations of the General Data Protection Regulation (GDPR), mandated elevated privacy safeguards. Although the project's implementation afforded enhanced data security measures, it remained essential to diligently account for data protection throughout the design and implementation phases. Consequently, the association between vital signs and participants' personal data was exclusively accessible to the respective primary care physicians and project study doctors, ensuring strict confidentiality. Additionally, we employed pseudonymization techniques to safeguard individual identities, and used industry-standard encryption methods for data transmission (Keil et al., 2022b). By pursuing this comprehensive and scientifically grounded approach, the project aimed to pave the way for a data-driven revolution in healthcare delivery, particularly in underserved rural regions. The outcomes of this endeavor held the potential to enhance medical outcomes, optimize resource allocation, and ultimately improve the overall well-being of individuals residing in these areas.

3 Technical implementation

Since we aim to evaluate under conditions that were as real as possible, i.e., not just as a demonstrator, a technical concept for the transmission of vital data was developed at an early stage. The system is intended to function as a stand-alone solution and cannot be integrated into existing systems such as practice management systems, care management systems, or the telematics infrastructure (TI). Key components included a mobile application capable of seamless data recording and transmission to a centralized database, as well as a web-based interface that enabled bidirectional data interaction. Vital signs are recorded using measuring devices that transmit the data to an iPhone via a Bluetooth interface. From the iPhone, the data is then sent via WLAN or an LTE connection to a cloud server that is certified for medical data. The physician can retrieve the data via secure access to a web interface. The data is presented in the web interface. The app as well as the web interface for the physicians were developed in close cooperation with all stakeholders. The app was developed natively for iOS in Swift. In addition, a mobile device management (MDM) system was used to improve the usability of the iPhone by keeping the functionality to a minimum.

Despite the robustness of the underlying infrastructure, the project necessitated the consideration of certain technical intricacies. For instance, data transfer protocols encompassed both wireless local area networks (WLAN) and long-term evolution (LTE) connectivity. Significantly, accommodating the needs of older participants, some of whom lacked WLAN connectivity within their residences, entailed providing alternative backup options utilizing LTE connectivity.

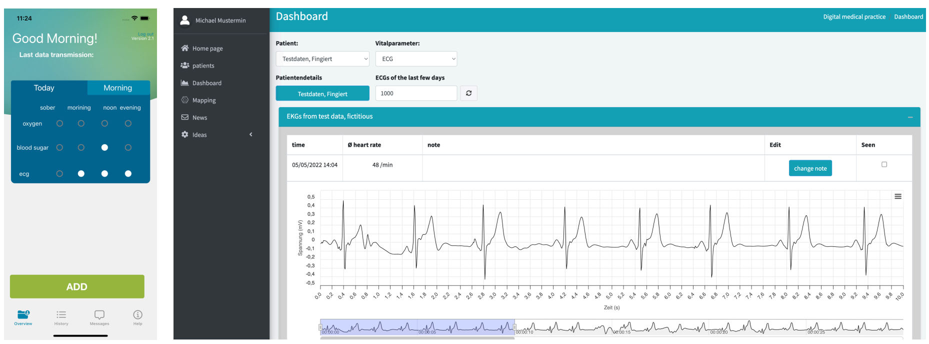

Figure 1. Screenshot of the applications for patients and GPs

4 Discussion and Conclusion

Despite some limitations and the constantly changing conditions caused by the Covid-19 pandemic, we were able to implement various measures. Through multi-stage iterations, the app and web interface for GPs and nurses were evaluated and adapted to the needs of the user groups. Close collaboration enabled the implementation of features that evolved only from conversations with stakeholders.

It became evident that different user groups have different requirements. While technology-interested patients were comfortable with the iPhone and wanted advanced features, technology-averse patients preferred a system without a smartphone. Connecting the meter directly to the cloud could be a simplification for this group. However, it is difficult to find a solution that meets all requirements. Therefore, different realizations should be considered to meet the needs of each subgroup. The choice of method and the usability of the system are important factors for the acceptance of the user groups. However, there is still room for improvement, and future developments should be done in close cooperation with the user groups.

The use of a flexible database system allowed the handling of different data types for the storage of vital signs data. A uniform definition of the data types would improve the interfaces between the different systems. A platform like a "digital twin" could give patients control over their data and provide access to healthcare stakeholders as needed.

On the front-end, measurement accuracy could be improved through various methods, such as gamification approaches involving contests and awards for reliable measurements and improvements in scores.

The project has faced some challenges, especially in terms of permanent funding. Public-private partnership approaches could play a role here, with companies providing support as part of workplace health promotion. The topic also opens avenues for further research in this area.

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References

Clemensen, J., Larsen, S. B., Kyng, M., & Kirkevold, M. (2007). Participatory design in health sciences: Using cooperative experimental methods in developing health services and computer technology. *Qualitative Health Research*, *17*(1), 122–130. https://doi.org/10.1177/1049732306293664

De Guzman, K. R., Snoswell, C. L., Taylor, M. L., Gray, L. C., & Caffery, L. J. (2022). Economic Evaluations of Remote Patient Monitoring for Chronic Disease: A Systematic Review. *Value in Health*, *25*(6), 897–913. https://doi.org/10.1016/j.jval.2021.12.001

Duque, E., Fonseca, G., Vieira, H., Gontijo, G., & Ishitani, L. (2019). A systematic literature review on user centered design and participatory design with older people. *IHC 2019 - Proceedings of the 18th Brazilian Symposium on Human Factors in Computing Systems*, 11–2019. https://doi.org/10.1145/3357155.3358471

El-Rashidy, N., El-Sappagh, S., Islam, S. M. R., M. El-Bakry, H., & Abdelrazek, S. (2021). Mobile Health in Remote Patient Monitoring for Chronic Diseases: Principles, Trends, and Challenges. *Diagnostics*, *11*(4), 607. https://doi.org/10.3390/diagnostics11040607

Farias, F. A. C. D., Dagostini, C. M., Bicca, Y. D. A., Falavigna, V. F., & Falavigna, A. (2020). Remote Patient Monitoring: A Systematic Review. *Telemedicine and E-Health*, *26*(5), 576–583. https://doi.org/10.1089/tmj.2019.0066

Harrington, C. N., Wilcox, L., Connelly, K., Rogers, W., & Sanford, J. (2018). Designing health and fitness apps with older adults: Examining the value of experience-based co-design. *ACM International Conference Proceeding Series*, 15–24. https://doi.org/10.1145/3240925.3240929

Kanis, M., Robben, S., Hagen, J., Bimmerman, A., Wagelaar, N., & Krose, B. (2013). Sensor monitoring in the home: Giving voice to elderly people. *Proceedings of the 2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops, PervasiveHealth 2013*, 97–100. https://doi.org/10.4108/ICST.PERVASIVEHEALTH.2013.252060

Keil, A., Hahn, K., Brombach, N., Brück, R., Farhan, N., & Gaus, O. (2022a). Acquisition and Processing of Biomedical Data for Outpatient Care in Rural Areas. *Current Directions in Biomedical Engineering*, *8*(2), 81–84. https://doi.org/10.1515/cdbme-2022-1022

Keil, A., Hahn, K., Brück, R., Brombach, N., Farhan, N., & Gaus, O. (2022b). Cloud-Based System for Vital Data Recording at Patients' Home. In E. Pietka, P. Badura, J. Kawa, & W. Wieclawek (Hrsg.), *Information Technology in Biomedicine* (S. 15–27). Springer International Publishing. https://doi.org/10.1007/978-3-031-09135-3_2

Kjeldskov, J., & Skov, M. B. (2007). Exploring context-awareness for ubiquitous computing in the healthcare domain. *Personal and Ubiquitous Computing*, *11*(7), 549–562. https://doi.org/10.1007/s00779-006-0112-5

Li, J., Wilson, L., Stapleton, S., & Cregan, P. (2006). Design of an advanced telemedicine system for emergency care. *ACM International Conference Proceeding Series*, *206*, 413–416. https://doi.org/10.1145/1228175.1228261

Martín-Lesende, I., Orruño, E., Mateos, M., Recalde, E., Asua, J., Reviriego, E., & Bayón, J. C. (2017). Telemonitoring in-home complex chronic patients from primary care in routine clinical practice: Impact on healthcare resources use. *European Journal of General Practice*, *23*(1), 136–143. https://doi.org/10.1080/13814788.2017.1306516

Nøhr, C., Villumsen, S., Bernth Ahrenkiel, S., Hulb&#230, & K, L. (2015). Monitoring Telemedicine Implementation in Denmark. In *MEDINFO 2015: EHealth-enabled Health* (S. 497–500). IOS Press. https://doi.org/10.3233/978-1-61499-564-7-497

Randall, N., Sabanovic, S., & Chang, W. (2018). Engaging older adults with depression as co-designers of assistive in-home robots. *ACM International Conference Proceeding Series*, 304–309. https://doi.org/10.1145/3240925.3240946

Righi, V., Sayago, S., & Blat, J. (2017). When we talk about older people in HCI, who are we talking about? Towards a 'turn to community' in the design of technologies for a growing ageing population. *International Journal of Human-Computer Studies*, *108*, 15–31. https://doi.org/10.1016/j.ijhcs.2017.06.005

Sekhon, H., Sekhon, K., Launay, C., Afililo, M., Innocente, N., Vahia, I., Rej, S., & Beauchet, O. (2021). Telemedicine and the rural dementia population: A systematic review. *Maturitas*, *143*, 105–114. https://doi.org/10.1016/j.maturitas.2020.09.001

Vaziri, D. D., Anslinger, M., Unbehaun, D., Wieching, R., Randall, D., Schreiber, D., & Wulf, V. (2019). Mobile health platforms for active and healthy ageing support in older adults: Design ideas from a participatory design study. *International Reports on Socio-Informatics (IRSI)*. https://dspace.ub.uni-siegen.de/handle/ubsi/1501

Weiser, M. (1999). The computer for the 21st century. *ACM SIGMOBILE Mobile Computing and Communications Review*, *3*(3), 3–11. https://doi.org/10.1145/329124.329126

Zachrison, K. S., Boggs, K. M., Hayden, E. M., Espinola, J. A., & Camargo, C. A. (2020). Understanding Barriers to Telemedicine Implementation in Rural Emergency Departments. *Annals of Emergency Medicine*, *75*(3), 392–399. https://doi.org/10.1016/j.annemergmed.2019.06.026