

# Adherence and acceptance of a home-based telemonitoring application used by multi-morbid patients aged 65 years and older

Journal of Telemedicine and Telecare  
2022, Vol. 28(1) 37–51  
© The Author(s) 2020



Article reuse guidelines:  
sagepub.com/journals-permissions  
DOI: 10.1177/1357633X20901400  
journals.sagepub.com/home/jtt



Caroline Lang<sup>1,2</sup> , Karen Voigt<sup>1</sup>, Robert Neumann<sup>3</sup>,  
Antje Bergmann<sup>1</sup> and Vjera Holthoff-Detto<sup>2,4</sup>

## Abstract

**Introduction:** Currently, there are only a small number of comprehensive study results on adherence and acceptance of telemonitoring applications (TMAs) regarding multi-morbid older patients. The ATMoSPHAERE study aimed to develop an information and communication platform for an intersectoral networking of, for example, general practitioners, therapists, social services and the multi-morbid older patient.

**Methods:** The study presented was designed as a longitudinal bicentric intervention study which focused on multi-morbid patients aged  $\geq 65$  years using home-based telemedical measurement and input devices. The development and testing of this TMA aimed to optimise patients' health care through intersectoral networking of all treating actors. Quantitative methods of data collection and analysis were used.

**Results:** Patients who completed the study were significantly younger than drop-outs and non-participants. The mental health of study patients significantly improved between the beginning and end of TMA use. The main reason for non-participation in the study was the high time expenditure when participating in the study. No perceived (information) benefits for health and insufficient content variety were the main reasons for drop-out. Appropriateness and handling of TMAs must be aligned with the needs of the heterogeneous user group of multi-morbid patients in order to increase acceptance and the added value of TMAs. Telemonitoring hardware should be oriented on functional capabilities of the older target group. Telemonitoring software content requires an individual, disease-specific approach for patients. The TMA should be unobtrusively integrated into usual daily life and be used to an appropriate extent according to the underlying disease in order to avoid stressing patients. With regard to adherence concerning TMAs, it is crucial to provide a contact person who is always available for patients having problems handling TMAs. Health concerns and questions can thus be addressed early, providing a feeling of safety in the care process.

**Discussion:** User acceptance of TMAs is an essential indicator and driver for use and for future implementation efforts in health care. In order to achieve maximum user centrality in development processes, patients must be involved as experts, co-designers and future users, considering their needs and perceptions.

## Keywords

Telemonitoring, telemedicine, patient acceptance, patient compliance, multi-morbidity

Date received: 6 November 2019; Date accepted: 22 December 2019

## Introduction

Demographic changes due to increasing life expectancy lead to a higher prevalence of chronic diseases and multi-morbidity – the coexistence of multiple diseases.<sup>1–3</sup> In Germany, the prevalence of multi-morbidity is rising with age.<sup>4</sup> Highly prevalent chronic diseases in Germany are cardiovascular diseases, cardiometabolic disorders and respiratory diseases.<sup>5</sup> The resulting higher need for medical care poses major challenges to health-care systems worldwide.

<sup>1</sup>Department of General Practice, Medical Clinic III, Medical Faculty, Technische Universität Dresden, Germany

<sup>2</sup>Department of Psychiatry and Psychotherapy, University Hospital Carl Gustav Carus at the Technische Universität Dresden, Germany

<sup>3</sup>Institute of Sociology, Philosophical Faculty, Technische Universität Dresden, Germany

<sup>4</sup>Department of Psychiatry, Psychotherapy and Psychosomatics, Alexianer Hospital Hedwigshöhe, St. Hedwig Hospital Berlin, Germany

### Corresponding author:

Caroline Lang, Technische Universität Dresden, Medical Faculty, Fetscherstraße 74, Dresden, 01307, Germany.  
Email: caroline.lang@ukdd.de

The primary-care sector – mostly in the gatekeeping role – will therefore be particularly strongly affected by these challenges, as the majority of patients aged  $\geq 65$  years treated by a general practitioner (GP) are multi-morbid.<sup>6,7</sup> Multi-morbid patients have a high level of physical and mental suffering, and it is often difficult and challenging for patients to understand the complexity of their medical conditions, the decisions regarding prioritisation of their health problems and their relevance to treatment.<sup>8,9</sup> A personal and often long-time relationship between patient and GP fosters holistic management of multi-morbidity.<sup>10</sup> Contextual knowledge of patient-specific living conditions helps GPs to prioritise the treatment of chronic diseases in the care process. However, GPs face challenges and limitations in this care process that impede meeting the multiple health-care needs of multi-morbid patients satisfactorily. Several national and international study results have revealed potential challenges due to existing structures such as fragmented care structures and a lack of communication and cooperation between GPs, specialists and other health professionals, as well as too little individual counselling and treatment time in general practice.<sup>11–14</sup>

Telemedicine as a field of application of eHealth in the medical and nursing care of patients has become increasingly important in recent years.<sup>15</sup> eHealth, especially the use of telemedicine, may have the potential to enhance the efficiency of physicians' activities in patient care processes, reduce their workload, reduce costs and increase the quality of clinical practice and care.<sup>16,17</sup> Supporting general practices through eHealth technologies may help to prevent over-, under- and misuse of health services.<sup>18</sup> However, the heterogeneous health-care systems and the different national eHealth policies and laws still determine the use of eHealth among GPs.<sup>19</sup> In Germany, the existing discourse on optimising the technological connection of stakeholders in health care has thus far hardly considered user perspectives.<sup>15</sup>

Acceptability (appropriateness of an intervention to be performed or received in health care<sup>20</sup>) and user acceptance (attitude towards a particular situation<sup>21</sup>) of telemedicine play decisive roles in the implementation of telemedicine applications into the daily routine of health-care providers and patients.<sup>21,22</sup> Currently, there are only a small number of comprehensive study results on the acceptance of telemedicine applications,<sup>21,23</sup> especially regarding multi-morbid geriatric patients.<sup>24</sup> The authors of a recent Cochrane review, which included 93 randomised controlled trials (RCT) and focused on telemonitoring of inter alia chronic conditions such as cardiovascular diseases and diabetes, pointed out that evidence on acceptability of telemedicine by patients and health professionals is limited.<sup>25</sup> Various observation, intervention and

qualitative studies conducted in primary care and community settings with elderly patients reported a high level of patient satisfaction<sup>26,27</sup> and acceptance of telemonitoring applications (TMAs).<sup>26,28</sup> TMA use was rated as simple<sup>29–31</sup> and showed a reduction in the patients' fear of new technologies,<sup>23</sup> and patients were adherent in the use of home-based telemedical measures.<sup>27</sup> Additionally, patients noted a subjective improvement, more detailed knowledge of their own health, as well as an increasing adherence to the treatment process.<sup>30</sup> Mehrabian et al. concluded that cognitively impaired patients in particular had difficulties in learning how to use telemedical devices.<sup>32</sup> To develop appropriate and manageable equipment for special user groups, it is crucial to involve patients as co-designers,<sup>33,34</sup> taking into account their preferences and needs. Knowing that contribution to the research is valued by developers and increases the quality of research, patients may feel more empowered, respected and also strengthened and supported regarding their cognitive ability, confidence and positive mood.<sup>33</sup>

Challenges have also been described in the existing literature concerning the usability of telemedical devices for patients.<sup>24,35</sup> Complications in patients seeing or hearing the physician during teleconsultations, as well as a lack of confidence in the telemedicine system, were reported.<sup>36</sup> Older patients were unable to figure out numbers on equipment buttons because of the colour contrast used,<sup>31</sup> which reaffirms the argument that unrestricted sight is essential for using TMAs.<sup>37</sup> Devices for the application of telemedicine software should be aligned with the specific needs of their users and tailored to their specific diseases, for example for people with osteoarthritis, tremor, visual and hearing impairments or even those who are illiterate, in order to exploit the potential of the technologies optimally.<sup>21,24,35,38,39</sup> Narasimha et al. pointed out in their review of usability studies that the usability of telemedicine applications (e.g. computer or telephone devices) is the main influencing factor for user acceptance.<sup>24</sup> However, the results of these studies could be limited by selection bias, since study patients were selected for study designs.

### *Aim of the study and research questions*

The main aims of the feasibility study 'Autonomy despite multi-morbidity in Saxony through patient empowerment, holistic care for older people with networking of all regional institutions and service providers' (ATMoSPHAERE) were the exploration, development and testing of a technology-based information and communication platform. The focus was on the intersectoral networking of several treating physicians in practices, nurses, therapists and social

services, patients with multiple chronic diseases and their caregivers. Furthermore, the usability and acceptance of the platform were analysed. The TMA aimed to be developed as an interoperable, controlled, open, secure, non-medical environment where patients can request home-based assistance and services from regional providers.

The research questions of the present analysis are: (1) How adherent are study patients regarding GP-prescribed vital data measurements via telemonitoring devices? (2) What reasons were associated with non-acceptance of the TMA by study patients? (3) What difficulties in the use of telemonitoring hardware and software were reported by study patients?

## Methods

The study was conducted between October 2015 and June 2019 and was funded by the German Federal Ministry of Education and Research (funding number 13GW0075F). Patient recruitment started in April 2016, and the last patient was recruited in March 2018. Follow-up data were collected until June 2018.

### Study design

The study presented was designed as a longitudinal bicentric intervention study. The study design was approved by the ethics committee at the Technische Universität Dresden (approval number 1012016). We performed the study in the two largest cities in Saxony (Dresden and Leipzig) – each with more than 500,000 inhabitants – to facilitate recruitment and to focus on GP practices with a specific interest in the medical treatment of elderly people.

#### Recruitment of GPs and study patients

**GPs.** GPs were partners within a network of accredited academic teaching practices in Dresden and a

network of geriatric specialists in Leipzig, respectively. Both were located in urban areas. The recruitment of the GPs was done during project presentation in a network meeting by the project team in which interested GPs were informed about the study and encouraged to participate. GPs who were interested in participating in the study were informed in detail about the study by the project leader and then signed a declaration of consent.

**Study patients.** GPs informed patients who met the study's inclusion and exclusion criteria (Table 1) and data protection and handed over detailed written information while patients were at their GP practice. Patients had the opportunity to ask questions and to discuss the study with their GP. To assess the eligibility of study patients, they were also screened by study assistants applying the Geriatric Basic Assessment (GBA), a tool measuring cognition (Mini-Mental State Examination (MMSE)<sup>40</sup> and clock-drawing test<sup>41</sup>), a tool measuring mobility (Timed Up and Go test (TUG)<sup>42</sup>) and a tool measuring independence in everyday life activities (Instrumental Activities of Daily Living assessment).<sup>43</sup> After eligibility was confirmed and patients decided to participate, they were consecutively included after signing the consent form for study participation and data storage. Furthermore, they were informed about the possibility of withdrawing from the study at any time – in which case, all patient data would be deleted. Patients who refused to participate ('non-participants') were asked for their reasons for not taking part but could also choose not to answer.

### Description of the telemonitoring process

The TMA was provided by the technical project partner Philips Medical Systems GmbH and consisted of the telemonitoring hardware ASUS ZenPad 7.0,

**Table 1.** Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> <li>• Age <math>\geq 65</math> years</li> <li>• Multi-morbidity (presence of at least two chronic diseases)</li> <li>• Capable of understanding patient information and consenting to the study</li> <li>• Independent operation of television via remote control and/or computer/laptop three or more times a week</li> <li>• Unimpaired hearing</li> <li>• Sufficient motoric and sensory speech ability</li> <li>• Sufficient eyesight to follow a television programme easily</li> </ul>	<ul style="list-style-type: none"> <li>• Missing capacity of consent</li> <li>• Unable to speak German fluently</li> <li>• Moderate to severe dementia according to ICD-10 (F03) or MMSE <math>&lt; 20</math></li> <li>• Motoric impairment (TUG: <math>\geq 30</math> seconds in initial measurement, 20–29 seconds in two repetition measurements)</li> <li>• Severe psychiatric co-morbidities (e.g. schizophrenic psychoses, addictions)</li> <li>• Currently participating in a comparable telemonitoring programme or participation within the last 12 months</li> </ul>

Samsung Tab 4, a sphygmomanometer, a pulse oximeter, weighing scales and the telemonitoring software Motiva (Figure 1).

Study assistants collected sociodemographic and health data (see Data Collection and Measures) and entered these into the telemedicine platform ATMOSPHERE ([www.atmosferaere.org](http://www.atmosferaere.org)), which served as an exchange base between health professionals. Data were then transferred to the Care Coordination Centre (CCC) at the German Red Cross (GRC) and to Motiva, a parallel telemedicine health platform providing data exchange between study patients and care and case managers (CCM). After receiving new patient-related data in Motiva, a GRC technician was sent to install the TMA in patients' homes ( $t_0$ ). Study patients were instructed in detail by the technician and performed the first use in his presence. After patients confirmed that they understood how to use the application, the project-specific care with the TMA started. From then on, study patients were provided with disease-specific care plans (e.g. health questionnaires and educational videos) via Motiva. After patient feedback, the platform was thoroughly upgraded during the study by, for example, recipe ideas for people with diabetes or hypertension, exercises for memory training and local event information.

According to the treatment recommendations of participating GPs, patients measured their vital signs, blood pressure (BP), heart frequency (HF), blood oxygen saturation ( $SpO_2$ ) and body weight (BWT) via measuring devices and answered health questionnaires on the tablet. The frequency of vital sign measurements were individually determined by GPs for each patient (once weekly, two to six times per week or daily). Vital data were transferred from measuring devices to the tablet and to the CCM at GRC, where staff constantly monitored patients during working hours and

critically assessed data for intervention if necessary. In cases where limit values were exceeded, targeted control questionnaires were sent to the patient immediately after the measurement was evaluated, and the responsible CCM contacted the patient first by telephone and, if necessary, subsequently provided immediate information to the treating GP, for example for acute intervention and/or prescription of medication or therapy.

After a period of 32 months, data collection ended, and the telemedical equipment was returned to the technical project partner Philips.

### Data collection and measures

The collection of sociodemographic and health data of study patients was computer based and took place at both study sites from April 2016 to June 2018. The study centre in Dresden was responsible for data maintenance. At the first face-to-face meeting after patient inclusion, the following data about the study patients were collected by study assistants while patients were at their GP practices: sex, age, marital status, current diagnoses according to ICD-10 and current vital signs (BP, HF,  $SpO_2$  and BWT). Data on school education level were collected during the first telephone interview with study patients within one week after the face-to-face meeting. The GBA was repeated after a participation time of six months ( $t_1$ ), 12 months ( $t_2$ ), 18 months ( $t_3$ ) and two years ( $t_4$ ) to monitor the health status of participants and to ensure primary health care as well as to explore factors necessary for improvement of project-specific health care.

To examine changes of symptoms of late-life depression, patients' health-related quality of life (QoL) and feeling of empowerment between  $t_0$  (baseline, installation of TMA),  $t_1$  (after six months with TMA) and  $t_2$  (after 12 months with TMA), study patients were interviewed by telephone using validated questionnaires

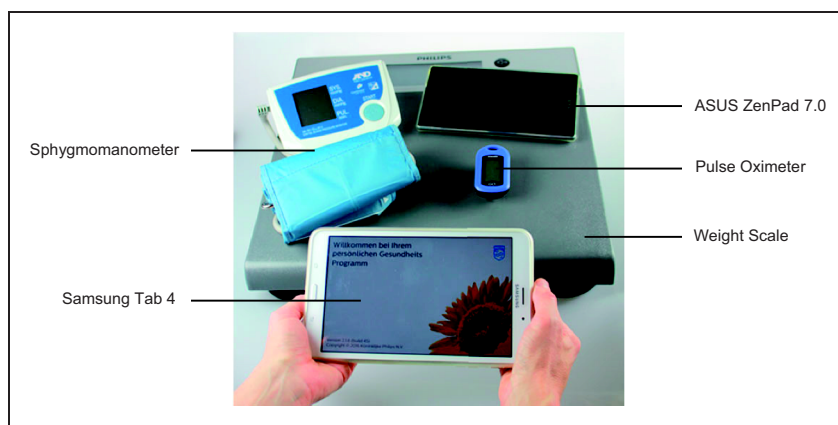


Figure 1. Telemonitoring application.

(Geriatric Depression Scale (GDS),<sup>44</sup> the 12-Item Short Form Health Survey (SF-12)<sup>45</sup> and the Empowerment Scale (ES)<sup>46</sup>). The GDS consists of 15 questions whose sum score differentiates depressive and non-depressive individuals. The simple dichotomous response format also enables patients with mild cognitive impairment to be screened with the GDS. Research on screening performance in the elderly revealed that the use of the GDS allows appropriate screening of very old individuals and reliable detection of major depression.<sup>47</sup> The SF-12 questionnaire includes 12 questions and covers eight dimensions (physical function, role physical, role emotional, bodily pain, vitality, social function, general health and mental health) using a Likert scale. The physical and mental component summary scales (PCS and MCS) represent the physical and mental health status of patients. Low scores indicate a worse health-related QoL and high scores a better health-related QoL.<sup>48</sup> The ES consists of 28 questions and seven factors describing the construct ‘empowerment’: self-efficacy, powerlessness, self-esteem, effecting change, optimism/control over future, righteous anger and group/community action. Patients can respond using a four-level Likert scale. The higher the summary score, the higher the patient’s feeling of empowerment.<sup>46</sup>

The collection of measured vital data was used as a database for the evaluation of adherence of study patients regarding GP-prescribed data measurements of vital signs. These were collected longitudinally and continuously from the beginning to the end of the telemedicine installation in patients’ homes. After completion of data collection, it was compared to the individual prescriptions by GPs. Philips was responsible for the storage of the measurement data; evaluation of these data was carried out by the study centre in Dresden.

Non-acceptance of the TMA by study patients was defined by drop-out (withdrawal from the study) and non-participation (refusing the study before consent). Possible reasons for drop-out were collected through computer-based telephone interviews or in a face-to-face meeting at the GP practice. Furthermore, all patients who were screened and included in the study but who decided to withdraw or not to participate were asked whether they were willing to discuss voluntarily the reasons for dropping out or non-participation with us. After exploring patient-specific reasons for non-acceptance of the TMA, categories were derived inductively from the explored reasons based on the statements of drop-outs and non-participants.

To evaluate challenges using the TMA, a self-developed questionnaire was applied during computer-based telephone interviews with study patients after 12 months of study participation ( $t_2$ ).

## Data analyses

Statistical analysis was performed using the statistical software IBM SPSS Statistics for Windows v25.0 (IBM Corp., Armonk, NY) and Stata v13 (StataCorp, College Station, TX). The statistical significance level  $\alpha$  was defined as 5% in all analyses. Sociodemographic data of all study patients, reasons for non-acceptance (drop-out or non-participation) and challenges in the use of the TMA were checked for plausibility and analysed descriptively by using frequency analyses for the selected samples. Independent-sample *t*-tests were used to explore significant differences between subgroups statistically. Data on measurements/transfer of vital data were analysed descriptively regarding their frequencies. Additionally, we modelled adherence, defined as the observed deviation between actual measurement frequencies and the prescribed measurement frequency per patient, by means of a difference score as:

$$\text{adherence}_{ij} = \text{actual measurement frequency}_{ij} - \text{prescribed measurement frequency}_{ij}$$

Values of zero indicated perfect adherence, while positive/negative values indicated over/under-measurement by patients. Analysis of patient-specific adherence has to account for the nested structure of the adherence data (measurements *i* nested in patients *j*), along with differences in the number of weeks that patients participated in the study (patient-specific sample size of measurements  $n_{ij}$ ) and the different schedules of measurements (daily, two to six days per week or weekly). Hence, we used a linear multilevel regression model to account for all the sources of variation in the adherence data simultaneously. We estimated three separate models for the vital data (HF/BP, SpO<sub>2</sub> and BWT) to test whether patients adhered to their prescribed schedule. Despite the rather small number of patients involved in the study, this approach has the benefit of using all the available measurement data across 52 weeks (see Table 5), and it allows for the control of the patient-specific differences in the number of measurements  $n_{ij}$  by giving less weight to data from patients with fewer observations.<sup>49</sup>

Patients who had only one or two measurements or none at all were defined as ‘non-measurers (0–2 measurements)’ and were dropped prior to the analysis of adherence data. Longitudinal data regarding late-life depression, health-related QoL and empowerment of all patients surveyed were analysed using analysis of variance with repeated measurements and non-parametric tests with stratification using the Friedman test. Health-related QoL was measured by the validated instrument SF-12 and its PCS and MCS scores.

These sum scales were analysed for statistical significance using paired-sample Wilcoxon signed-rank tests.

## Results

### Sample description

**Participating general practices.** A convenience sample of nine GPs were recruited to participate in the project: three in Dresden from a network of accredited academic teaching practices and six in Leipzig from a network of geriatric specialists.

### Study patients, drop-outs and non-participating patients.

In total, 257 patients were screened for possible participation at both study sites by performing the GBA (Figure 2). Of the 257 screened patients, 177 (68.9%) were finally included in the study (Dresden  $n=135$ , Leipzig  $n=42$ ) based on the inclusion criteria. Overall, 116 (65.5%) of the study patients were actively involved in the study and the home-based TMA. Of these participants, 34.5% ( $n=61$ ) decided to withdraw before the end of the study (drop-outs). Additionally, seven (4.0%) patients died during the study period. A total of 80 (31.1%) patients screened for study inclusion refused to participate in the study (non-participants).

Sociodemographic data are summarised for all patients assessed as eligible and included in the study (Table 2). The mean age of all included patients was 79.6 years (standard deviation ( $SD$ )=5.6). Patients who completed the study were significantly younger than drop-outs ( $p=0.004$ ) and non-participants ( $p=0.001$ ). Information on school education level could

only be obtained from 150 patients during the first telephone interview after installation of the TMA because 20 (32.8%) study patients had already withdrawn from the study at this time, and four (6.5%) study patients refused to provide information about their school education level.

Of all participating patients, 66.7% (118/177) were diagnosed with two to nine chronic diseases, 22.0% (39/177) had 10–19, 8.5% (15/177) had 20–29 and 2.8% (5/177) were diagnosed with more than 30 chronic diseases. The most prevalent chronic conditions in our study cohort were essential hypertension (75.1%; 133/177), disorders of lipoprotein metabolism and other lipidaemias (38.4%; 68/177) and type 2 diabetes mellitus (31.6%; 56/177; Table 3).

### Extent of change in late-life depression, health-related QoL and empowerment.

During the study and use of TMA, patients were longitudinally screened with validated questionnaires at  $t_0$  (enrolment/installation of TMA),  $t_1$  (after six months) and  $t_2$  (after 12 months) for clinical symptoms of late-life depression,<sup>44</sup> health-related QoL<sup>48</sup> and the feeling of empowerment in old age<sup>46</sup> (Table 4). Mean rank values of late-life depression and empowerment remained almost constant throughout the study between  $t_0$ ,  $t_1$  and  $t_2$ . Also the mean rank of the physical component score showed no statistically significant changes during the study. Changes in MCS scores were statistically significant between  $t_0$  and  $t_1$  ( $p=0.01$ ) and between  $t_0$  and  $t_2$  ( $p=0.008$ ). According to the German Norming Sample,<sup>48</sup> the arithmetic mean for both sexes at the age of  $\geq 70$  years is 41.69 ( $SD=12.1$ ) for the PCS score and 52.44 ( $SD=9.9$ ) for the MCS score. Both PCS and MCS results differed

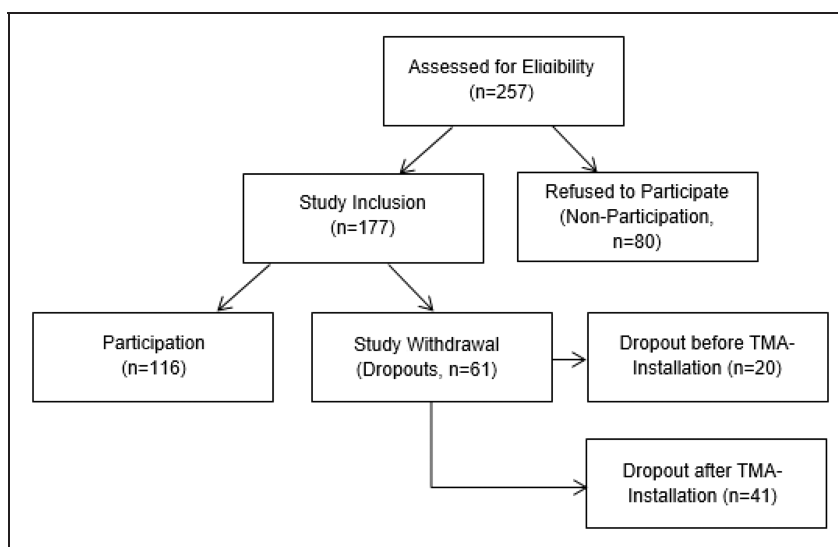


Figure 2. Patient recruitment flow chart.

**Table 2.** Sociodemographic characteristics.

	Inclusion, % (n)	Participation, % (n)	Drop-outs, % (n)	Non-participation, % (n)
Total screened (n = 257)	68.9 (177)	65.5 (116)	34.5 (61)	31.1 (80)
Sex				
Male	36.7 (65)	34.5 (40)	42.6 (26)	36.3 (29)
Female	63.3 (112)	65.5 (76)	57.4 (35)	61.3 (49)
Missing	–	–	–	2.5 (2)
Age				
Mean age in years (SD)	79.6 (5.6)	78.8 (5.3) <sup>*/**</sup>	81.3 (5.8) <sup>*</sup>	82.2 (5.7) <sup>**</sup>
65–75	19.8 (35)	24.1 (28)	19.7 (12)	16.3 (13)
76–85	66.1 (117)	64.7 (75)	60.6 (37)	51.2 (41)
≥86	14.1 (25)	11.2 (13)	19.7 (12)	30 (24)
Missing	–	–	–	2.5 (2)
Marital status				
Alone/widowed	42.9 (76)	44.8 (52)	42.6 (26)	42.5 (34)
Married/cohabiting	57.1 (101)	55.2 (64)	57.4 (35)	55.0 (44)
Missing	–	–	–	2.5 (2)
School education level				
Low (≤9 years)	40.7 (72)	47.4 (55)	27.9 (17)	–
Mid (10 years)	17.5 (31)	21.6 (25)	9.8 (6)	–
High (11–13 years)	26.6 (47)	28.4 (33)	23 (14)	–
Missing	15.2 (27)	2.6 (3)	6.5 (4)	–
Dropped out prior to installation	–	–	32.8 (20)	–

\* $p = 0.004$ ; \*\* $p = 0.001$  (independent-sample  $t$ -test).

SD: standard deviation.

**Table 3.** Ten most prevalent chronic conditions of study patients.

ICD-10 diagnoses	Description	Patients, n (%)
I10	Essential (primary) hypertension	133 (75.1)
E78	Disorders of lipoprotein metabolism and other lipidaemias	68 (38.4)
E11	Type 2 diabetes mellitus	56 (31.6)
I48	Atrial fibrillation and flutter	39 (22)
Z92	Personal history of medical treatment	38 (21.5)
I25	Chronic ischaemic heart disease	
I50	Heart failure	36 (20.3)
K76	Other diseases of liver	31 (17.5)
M17	Gonarthrosis (arthrosis of the knee)	27 (15.3)
N18	Chronic kidney disease	
M54	Dorsalgia	25 (14.1)
R42	Dizziness and giddiness	23 (13)

from the norm in our cohort, with slightly higher scores, indicating that our study patients had slightly better physical and mental health. Regarding our results, it can be assumed that the mental health of patients improved between the beginning and the end of TMA use.

### Adherence of patients with the TMA used

After inclusion, study patients were equipped with a tablet to use the Motiva software and to measure

vital data. Vital data measurements were saved and transferred via Bluetooth to the CCC for screening and determination of the necessity for intervention in case of limits being exceeded (Table 5).

In order to monitor chronic diseases, GPs used the ATMoSPHAERE platform to monitor the vital signs of patients participating in the study. The focus of the analysis was whether participants adhered to the measuring schedules as prescribed by the GPs. The first set of models investigated the adherence<sub>*ij*</sub> of BP/HF, SpO<sub>2</sub> and BWT measurements of patient<sub>*j*</sub> across the 52 study weeks via a linear multilevel regression model without any sociodemographic information. The analysis of deviations in BP/HF measuring frequency revealed that patients who had to perform measures on a weekly basis did so less often than ordered by GPs. In contrast, patients who had to measure their BP/HF more than once a week or daily performed measurements more often than prescribed by the GP. Patients performed on average 2.2 more measurements of BP/HF per week when they had been asked to send data daily, and patients who were asked to measure BP/HF two to six days per week sent an average of 5.0 additional measurements per week (see Figure A1 in the Appendix). There are no significant differences in the results depending on whether drop-outs were included or excluded in the analysis. Measurement patterns of SpO<sub>2</sub> revealed that only patients with daily

**Table 4.** Extent of change in late-life depression, health-related quality of life and empowerment.

	Late-life depression, mean rank (n)	Health-related quality of life, mean rank (n; mean; SD)		Empowerment, mean rank (n; mean; SD)
		PCS score	MCS score	
t <sub>0</sub>	2.00 (155)	1.91 (144; 41.60; 10.3)	1.73 <sup>*/**</sup> (144; 53.62; 8.6)	2.02 (144; 2.06; 0.2)
t <sub>1</sub>	1.97 (127)	2.11 (111; 43.18; 9.6)	2.13 <sup>*</sup> (111; 56.06; 6.5)	1.98 (111; 2.03; 0.2)
t <sub>2</sub>	2.04 (111)	1.98 (87; 42.49; 10.1)	2.14 <sup>**</sup> (87; 55.63; 7.7)	2.00 (87; 2.05; 0.2)

\*p=0.01; \*\*p=0.008 (Wilcoxon signed-rank test), 95% confidence interval.

PCS: physical component scale; MCS: mental component scale.

**Table 5.** Measurement frequencies of BP/HF, SpO<sub>2</sub>, BWT and mean adherence (pooled).

	Patients, n (%)	Measurements, n	Mean adherence (SD)	Min	Max
<b>BP/HF</b>					
Patients	110 (70.51)	5245			
Drop-outs	44 (28.21)	885			
Non-measurers (0–2 measurements)	2 (1.28)	2			
Total	156 (100)	6132	0.07 (5.28)	–7	12
<b>SpO<sub>2</sub></b>					
Patients	40 (71.43)	1870			
Drop-outs	13 (23.21)	302			
Non-measurers (0–2 measurements)	3 (5.36)	5			
Total	56 (100)	2177	2.34 (4.26)	–6	12
<b>BWT</b>					
Patients	49 (38.58)	1854			
Drop-outs	41 (32.28)	376			
Non-measurers (0–2 measurements)	37 (29.14)	43			
Total	127 (100)	2273	1.54 (3.75)	–6	12

BP: blood pressure; HF: heart frequency; SpO<sub>2</sub>: blood oxygen saturation; BWT: body weight.

target measurements tended to surpass their prescribed measurement schedule by an average of 2.2 (including drop-outs) to 2.4 measurements (without drop-outs) per week. Finally, the models were analysed with additional sociodemographic information about participants for all three groups of measurement frequencies with and without drop-outs to examine the influence of age, sex, marital status and level of school education on patient adherence (see Figure 3). As shown, only the prescribed measurement schedules are able to explain the observed level of adherence. There are no significant differences between the sociodemographic characteristics of study patients and their adherence with the TMA used.

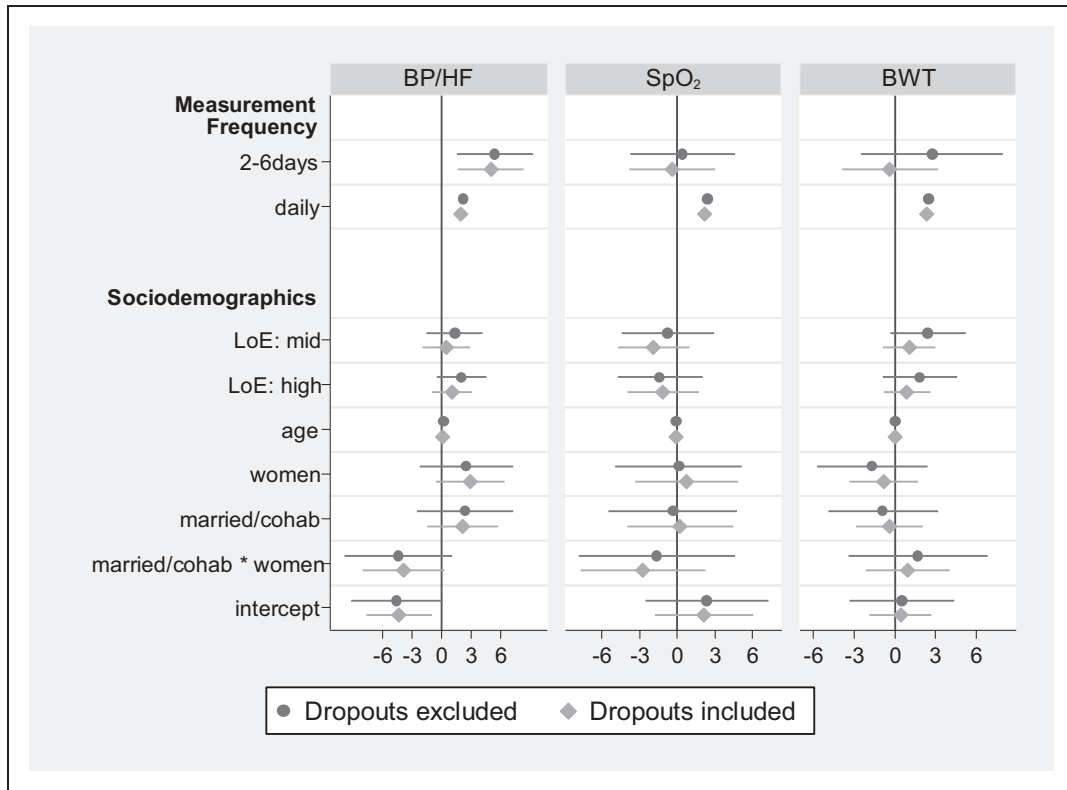
### Reasons for non-acceptance of the TMA by patients

**Non-participants.** Patients who were eligible for study participation but who decided not to participate were described as non-participants. The majority of non-participants (97.5%; 78/80) were voluntarily willing to explain what led to their decision in an individual interview. The following categories were derived inductively

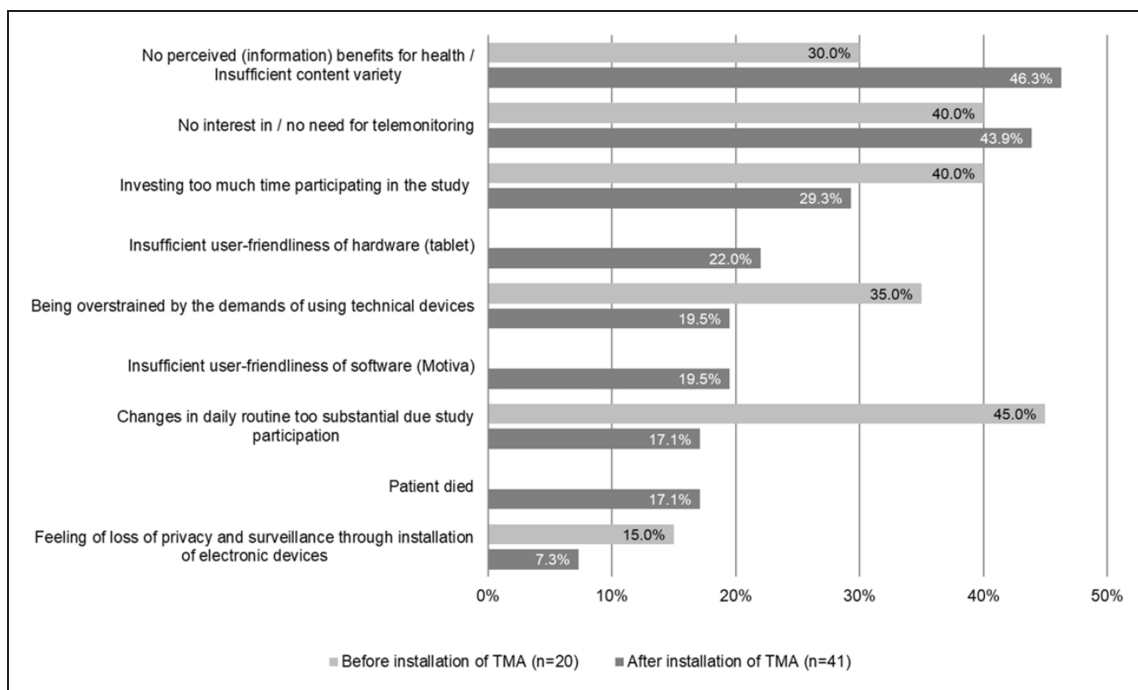
from the concerns stated by non-participants: investing too much time when participating in the study (38.5%; 30/78); no interest in/no need for telemonitoring (35.9%; 28/78); being too challenged by the use of new and unfamiliar technical devices (17.9%; 14/78); the need to change their daily routines due to study participation (14.1%; 11/78); and feeling of a loss of privacy and surveillance if electronic devices were installed in their private homes (14.1%; 11/78).

**Drop-outs.** Participants who initially consented to participate in the study but who withdrew from the study during its course are referred to as drop-outs. There was a drop-out rate of 34.5% (61/177). Of these, 20 (32.8%) participants withdrew their consent prior to installation of the TMA, and 41 (67.2%) participants withdrew after installation of the TMA. From the total cohort of drop-outs, 88.5% (54/61) of patients gave reasons for dropping out, and seven (11.5%) patients died during the study. The following categories were derived inductively from the explored patient-specific reasons (Figure 4): no perceived (information) benefits





**Figure 3.** Multilevel regression estimation results (with 95% confidence interval) of patient-specific adherence to prescribed measurement schedule. Adherence is measured as the difference between actual and prescribed measurement schedule and controlled for sociodemographic data of participants, for samples with and without drop-outs. LoE: level of school education; cohab: cohabiting.



**Figure 4.** Reasons for dropping out before and after installation of telemonitoring application (n = 61; multiple answers possible).

for health/insufficient content variety; no interest in/need for telemonitoring; investing too much time participating in the study; insufficient user-friendliness of hardware (tablet); insufficient user-friendliness of software (Motiva); being stressed by the demands of using technical devices; changes in daily routine too substantial due to study participation; and feeling a loss of privacy and surveillance through installation of electronic devices.

The most mentioned reasons for dropping out after installation of the TMA were no perceived (information) benefits and the insufficient content variety (46.3%; 19/41), as well as the lack of interest in/need for telemonitoring (43.9%; 18/41). In contrast, only 30% (6/20) complained about missing (information) benefits and insufficient content variety before installation of the TMA. It was also striking that more patients considered the changes in daily routine due to study participation to be too substantial before installation of the TMA (45%; 9/20) than after installation (17.1%; 7/41). A similar picture can be seen regarding the feeling of loss of privacy and surveillance: 15% (3/20) stated this as a reason for withdrawing before installation of the TMA compared to only 7.3% (3/41) after installation. Being stressed by the demands of using technical devices was mentioned by 35% (7/20) of study patients before installation of the TMA but only by 19.5% ( $n=8/41$ ) after installation. A total of 40% (8/20) of patients feared that they would invest too much time participating in the study before installation, but only 29.3% (12/41) mentioned this as a reason for dropping out after installation of the TMA. Nearly the same number of patients complained about the insufficient user-friendliness of the hardware (22%; 9/41) and software (19.5%; 8/41).

### **Patient-reported challenges using the TMA**

**Hardware (tablet).** Study patients reported two major issues they faced in using the telemonitoring hardware: difficulties operating the on/off button on the tablet and low touch sensitivity were reported as usage barriers of the devices by 11.5% (13/113) of all interviewed study patients. Malfunctions of the devices (e.g. recurring flight mode setting) hindered 5.3% (6/113) of study patients from working with the tablet.

**Software (Motiva).** Of all interviewed patients, 23% (26/113) reported that applied health-related questionnaires were too undifferentiated and untailored regarding their chronic diseases. Missing or untailored feedback regarding sent vital data or answered questionnaires and the lack of a dialogue option were complained about by 5.3% (6/113) of patients. Software icon and font sizes being too small were criticisms by

3.5% (4/113) of study patients. Just as many patients (3.5%; 4/113) reported other problems, which included complaints about inaccurate measurements in contrast to their own home vital data measurement systems and the unclearly structured user interface.

**Internet connection.** Internet availability was necessary to ensure the transmission of, for example, vital signs and questionnaire results from patients' tablets to the CCC, thus ensuring project-specific monitoring. A slow or missing Internet connection was reported by 23% (26/113) of interviewed study patients.

## **Discussion**

### **Summary and discussion of main findings**

The results of our study make an important contribution to the implementation research of telemonitoring applications in multi-morbid patients aged  $\geq 65$  years. We have uncovered aspects that limit the usability of telemedical hardware and software, and presented patient-related motives that reduce the acceptance of TMAs. Furthermore, we were able to achieve results demonstrating heterogeneous adherence behaviour of study patients regarding the GP-prescribed regime and TMA use.

Our study findings revealed a significant difference regarding the age of study patients, with an average age of 78.8 years ( $SD=5.3$ ), between non-participants ( $p=0.001$ ) and study patients who dropped out ( $p=0.004$ ).

One third (34.5%) of the study patients withdrew from the study prematurely ('drop-outs'). According to our results of drop-out reasons, a large proportion of patients who left the study after the home-based installation of the TMA did not perceive (information) benefits for health and thought there was insufficient content variety in the use of TMA, as well as having no interest in or need for telemonitoring. In a systematic review, Gorst et al.<sup>50</sup> analysed studies focusing on patients' acceptance or perceptions of telehealth, included participants with chronic diseases with a mean age of 68 years, and reported an average drop-out rate of 20%. The main drop-out reasons were the unwillingness of participants to use telehealth devices, deterioration of health conditions and technical problems. These reasons differ from our main findings. However, our study patients also reported technical problems related to telemonitoring hardware and quality of the Internet connection. Intervention study results which were published by Domingo et al.<sup>51</sup> showed a drop-out rate of 32.9%, which concurs with our study findings. In their research paper, they described an application similar to our TMA and

focused on feasibility, acceptance, satisfaction and behavioural changes for people suffering from heart failure with a mean age of 67 years. About 8% of patients in the study reported by Domingo et al. withdrew after consent and before installation of the TMA in patients' homes. In contrast, our results showed a much higher rate for this target group (32.8%). The main reasons for drop-out reported by Domingo et al. were patient reluctance to use the system and incidents related to telemonitoring equipment, including lack of Internet coverage.

Out of all patients screened as eligible, 31.1% refused participation in our study ('non-participation'), which corresponds to the results of other studies.<sup>50,51</sup> The most mentioned reasons for non-participation in our study were concerns about investing too much time participating in the study and having no interest/need for telemonitoring, which also confirms reported reasons in the studies by Gorst et al. and Domingo et al. cited above. Domingo et al. described the inability to carry out telemonitoring at home as another reason, which was also partly reported by our patients. Subramanian et al.<sup>52</sup> conducted research on a home-based telemedicine intervention. In accordance with our study findings, the authors revealed reasons for non-participation as the lack of the perceived benefits of TMAs and the fear of being stressed by the technical application. Several research findings also indicated a higher likelihood of non-participation by older people due to the stress caused by technology, lower affinity with technology<sup>39,51,53</sup> or anxiety using technology.<sup>54,55</sup> In a cross-sectional study, Foster et al. also disclosed reasons for study refusal which were related to technology: time and interest.<sup>37</sup>

Comparing non-participants to drop-outs, it can be seen that concern or experience of changing daily routines due to study participation was stated by 14.1% of non-participants but by 45% of drop-outs. A similar pattern can be seen between both groups regarding concern or experience of being stressed by the demands of using technical devices (19.9% and 35%, respectively). It can be concluded that patients' habits in their daily routines were restricted decisively due to the obligation to provide regular measurements at fixed times as well as dealing with the technical devices. Patients may be annoyed by technology dominating their everyday lives. Advancing technology to non-contact and indirect measurement of vital data may be a way to maintain patients' daily routines and habits while still being monitored and feeling safe.

The mental health of study patients significantly improved between the beginning and end of TMA use ( $p=0.008$ ). Patients may have felt more comfortable with the closely focused care and empowered in managing their own health or even being involved in a study. In

line with this, Rahimpour et al.<sup>55</sup> reported findings from focus group interviews with patients suffering from chronic diseases. They rated a home telemedicine system and reported benefits for patients such as improved peace of mind and empowerment to participate in their own health management. Lee et al.<sup>56</sup> published results from semi-structured interviews with diabetics using telehealth for disease management. Patients appreciated the continuity of monitoring and care which increased the feeling of security and comfort. This need for security and comfort regarding patients' own health status may also have had an impact on patient measurement behaviour: study patients who had to measure vital data once per week were less adherent and measured on average fewer vital data than prescribed by their GPs. In contrast, daily measurers of all measuring types (BP/HF, SpO<sub>2</sub>, BWT) on average exceeded their prescribed measuring frequency of vital data. It can be assumed that only the target group that was supposed to take daily measurements tends to perform their measurements more often than intended. An over-measurement of vital data, however, holds the risk of oversupply regarding vital data measurements. It can also increase patients' uncertainty about their own health – uncertainty which would not exist without the use of the TMA. This aspect was also described by Sanders et al., who reported results from the Whole System Demonstrator programme, a large RCT of telehealth and telecare, including patients with a mean age of 71 years suffering from chronic diseases.<sup>39</sup> Moreover, difficulties with Internet connectivity and failed transmissions of vital data may also have led to over-measurement. Recurring difficulties in the quality of the Internet connection and technical problems in the use of telemedical hardware are also well described in the existing literature.<sup>50,55,57,58</sup> A slow or missing Internet connection was criticised by more than a quarter of our study patients as being the main problem in handling telemedical hardware and indicates that broadband availability is still a persistent problem in Germany. Results of an empirical study with geriatric patients<sup>59</sup> are consistent with these findings: study patients were concerned about the quality of the Internet connection whilst using telemedicine devices due to a low-speed broadband connection. Although broadband availability in Germany is increasing, it is still not sufficient in all regions of the country.<sup>60</sup>

Related to the Motiva software, our study patients perceived that the questionnaires offered on the tablet were too undifferentiated and untailored, which hampered software handling. Moreover, they missed dialogue options with their CCMs and/or GPs to receive a timely response to questions. This indicates that content-related offers on the tablet must be adapted to the target group in order to generate added value and variety of content. The need for a tailored

design targeting users has also been disclosed in the existing literature.<sup>17</sup>

The multi-morbid participants included in the study presented co-morbidities in line with data by the German Health Report 2015<sup>61</sup> and findings of a project on patients with multi-morbidity and polypharmacy<sup>62</sup> regarding top 10 long-term diagnoses in primary care. There was 80% accordance regarding common long-term diagnoses between these studies and our patient cohort.

### *Recommendations based on our results*

Before starting any TMA development process, a detailed preliminary analysis of the cohort and involvement of appropriate patients is required to tailor the TMA to the specific patient group. Future telemonitoring projects need to consider and address challenges we revealed in this study in order to provide multi-morbid older patients with the greatest possible comfort in handling telemedical devices. In order to achieve maximum user centricity, the development process as well as patients' views and attitudes must be continuously evaluated by the target group. In this sense, patients must be involved as experts, co-designers and future users to consider their needs and perceptions. Existing problems such as low user friendliness of hardware and software that impede an optimal use of the TMA can thus be targeted and eliminated more quickly. Even patients with mild cognitive impairments can benefit from participating in the TMA development process by being appreciated for their contribution, which strengthens their confidence and empowerment, stabilises cognitive abilities and positively shapes their illness experience,<sup>33,34</sup> and by pointing out needs which should be especially considered for this target group.

Our findings revealed that acceptance of telemonitoring in the population presented here would have improved by a dialogue option permitting communication between patients and their GPs and/or their CCMs via the tablet. For safe and easy handling of telemonitoring hardware and software, patients need an easily accessible personal contact ('hotline') who can assist with questions concerning the technical or content handling. To avoid stressing patients with technology, TMAs should be unobtrusively integrated into the usual daily routine of patients and be used to an appropriate degree.<sup>63</sup> In this sense, we recommend theory-based and practice-oriented days of introduction in order to increase technology-specific knowledge and technical competence. Thus, concerns about the use of telemedicine devices can be addressed early on and the motivation and self-confidence in the patients' own abilities strengthened. Easy handling of the telemonitoring measures and input devices seems to be just as important

for better patient-related acceptance as tailored content variety in the software. Integrated questionnaires assessing patients' health status, some of which should be answered on a daily basis, need to be tailored to disease-specific conditions in order to ensure more targeted care for the multi-morbid patient group. It is important to consider patients who need specific information about their diseases, recommendations and support, for example through social services, because they are not able to handle everyday activities by themselves. Patients who consider themselves – in spite of their existing multi-morbidity – as still being too active and independent in daily life must also be taken into account. In order to guarantee these patients improved health care by means of accompanying telemonitoring, the perceived added value and benefit for their own health-care needs is essential<sup>64</sup> and provides strong evidence regarding efficacy of the TMA for this patient group. Contents such as health prevention and activation should be considered when developing needs-tailored and varied software. Offers with food recipes for specific diseases, memory training features or current local event information are valuable and helpful additive software content. Our findings and recommendations will help future implementation processes to increase acceptance of TMAs by multi-morbid older patients and to design TMAs in a tailored and sustainable manner.

### *Implications for future telemedicine implementation efforts*

The present study contributes to the field of telemedicine research with important findings on adherence and acceptance of a TMA by multi-morbid older patients that should be considered in future applications of telemonitoring. User acceptance of TMAs is an essential indicator and driver for the use and implementation efforts in standard health care. Future research should focus further on the usability of TMAs and user acceptance. In these terms, it should be considered that the acceptance of TMAs by professional users, for example GPs, CCMs and study assistants, is also highly relevant.

### *Limitations and strengths*

The sample size represents a convenience sample and claims no representability. Selection bias could exist, as GPs were selected from a network of accredited academic teaching practices, and patients who were found to be eligible for participation were selected by study GPs but could also refuse study participation. The telephone survey with study patients was carried out as a panel survey, a repeated examination of a random sample. The advantage of such a survey type is the cost and time efficiency, which has been confirmed in the period

of this data collection. Another benefit is the reduction of possible scepticism of patients through repetitive interview waves and familiar interviewers. However, a panel survey also has the difficulty that study subjects may be affected by repetition of questions in their response behaviour (response bias), which may ultimately affect the informative value of the data collection.<sup>65</sup> Moreover, it is possible that social desirability bias occurred during telephone interviews. Also, people may have behaved differently because they knew that they were participating in a study and were under observation (Hawthorne effect). To avoid such effects and to measure the effectiveness of telemedicine interventions as well as to clarify causalities in future telemedicine studies, a controlled study design is recommended which was not applied in the present study. The partly difficult study conditions (technical equipment and insufficient Internet quality) may have caused patients to drop out who would otherwise have continued participation under better conditions. However, these conditions reflect realistic challenges in the use of TMAs in the daily care of patients.

### Acknowledgements

We thank our consortium partners and study physicians of the ATMoSphaere project for their constructive cooperation. Special thanks go to our study patients, who significantly contributed to new findings in the research field of telemedicine applications with their participation in telephone and personal interviews. The development of the presented telemedicine system was supported by the German Federal Ministry of Education and Research within the funding programme 'Medical Technology Solutions for Multimorbidity' under grant agreement number 13GW0075F.

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

### Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

### ORCID iD

Caroline Lang  <https://orcid.org/0000-0003-2747-4559>

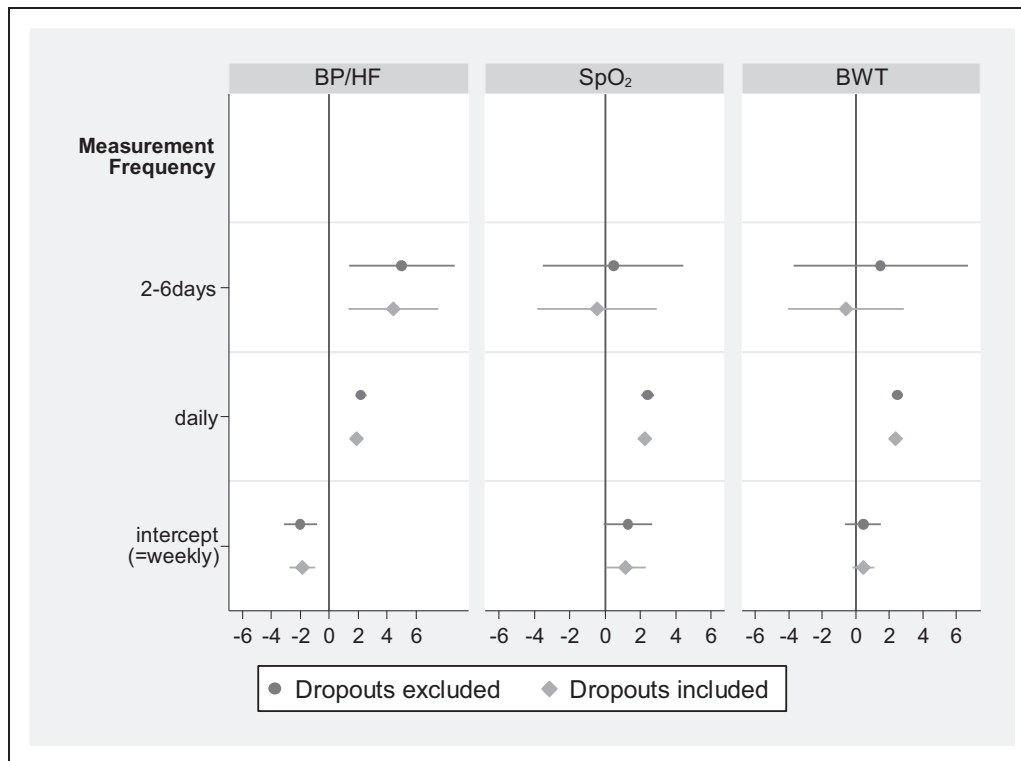
### References

- Vetrano DL, Calderon-Larranaga A, Marengoni A, et al. An international perspective on chronic multimorbidity: approaching the elephant in the room. *J Gerontol A Biol Sci Med Sci* 2017; 73: 1350–1356.
- Marengoni A, Angleman S, Melis R, et al. Aging with multimorbidity: a systematic review of the literature. *Ageing Res Rev* 2011; 10: 430–439.
- World Health Organization. *Multimorbidity: technical series on safer primary care*. Geneva: World Health Organization, 2016.
- Fuchs J, Busch M, Lange C, et al. Prevalence and patterns of morbidity among adults in Germany. *Bundesgesundheitsbl* 2012; 55: 576–586.
- Robert Koch Institut. *Wie gesund sind die älteren Menschen? Gesundheit in Deutschland Gesundheitsberichterstattung des Bundes – Gemeinsam getragen von RKI und Destatis*. Berlin: Robert Koch Institut, 2015.
- Starfield B, Lemke KW, Bernhardt T, et al. Comorbidity: implications for the importance of primary care in 'case' management. *Ann Fam Med* 2003; 1: 8–14.
- Violan C, Foguet-Boreu Q, Flores-Mateo G, et al. Prevalence, determinants and patterns of multimorbidity in primary care: a systematic review of observational studies. *PLoS One* 2014; 9: e102149.
- Wallace E, Salisbury C, Guthrie B, et al. Managing patients with multimorbidity in primary care. *BMJ* 2015; 350: h176.
- Rechel B, Grundy E, Robine JM, et al. Ageing in the European Union. *Lancet* 2013; 381: 1312–1322.
- Luijckx HD, Loeffen MJ, Lagro-Janssen AL, et al. GPs' considerations in multimorbidity management: a qualitative study. *Br J Gen Pract* 2012; 62: e503–510.
- Sinnott C, Mc Hugh S, Browne J, et al. GPs' perspectives on the management of patients with multimorbidity: systematic review and synthesis of qualitative research. *BMJ Open* 2013; 3: e003610.
- Lang C, Gottschall M, Sauer M, et al. Da kann man sich ja totklingeln, geht ja keiner ran – Schnittstellenprobleme zwischen stationärer, hausärztlicher und ambulanzfachspezialisierter Patientenversorgung aus Sicht Dresdner Hausärzte. *Gesundheitswesen* 2019; 81: 822–830.
- Van Den Bussche H, Schon G, Kolonko T, et al. Patterns of ambulatory medical care utilization in elderly patients with special reference to chronic diseases and multimorbidity – results from a claims data based observational study in Germany. *BMC Geriatr* 2011; 11: 54.
- Luijckx HD, Lagro-Janssen ALM and Van Weel C. Multimorbidity and the primary healthcare perspective. *J Comorb* 2016; 6: 46–49.
- Dockweiler C and Razum O. [Digital health: new challenges for public health]. *Gesundheitswesen* 2016; 78: 5–7.
- Codagnone C and Lupiañez-Villanueva F. *Final report – benchmarking deployment of eHealth among general practitioners 2013 (SMART 2011/0033)*. Luxembourg: European Commission, 2013.
- Saigi-Rubio F, Jiménez-Zarco A and Torrent-Sellens J. Determinants of the intention to use telemedicine: evidence from primary care physicians. *Int J Technol Assess Health Care* 2016; 32: 29–36.
- Gersch C and Ebel M. [Both patients and physicians benefit from Internet-based communication (APIKAP study)]. *MMW Fortschr Med* 2014; 156: 31–38.
- Ortega Egea JM, Gonzalez MV and Menéndez MR. eHealth usage patterns of European general practitioners:

- a five-year (2002–2007) comparative study. *Int J Med Inform* 2010; 79: 539–553.
20. Sekhon M, Cartwright M and Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. *BMC Health Serv Res* 2017; 17: 88.
  21. Dockweiler C. Akzeptanz der Telemedizin. In: F Fischer and A Krämer (eds) *eHealth in Deutschland: Anforderungen und Potenziale innovativer Versorgungsstrukturen*. Berlin: Springer, 2016, pp.257–271.
  22. Cook EJ, Randhawa G, Sharp C, et al. Exploring the factors that influence the decision to adopt and engage with an integrated assistive telehealth and telecare service in Cambridgeshire, UK: a nested qualitative study of patient ‘users’ and ‘non-users’. *BMC Health Serv Res* 2016; 16: 137.
  23. Karg O, Weber M, Bubulj C, et al. Akzeptanz einer telemedizinischen Intervention bei Patienten mit chronisch-obstruktiver Lungenerkrankung. *Deut Med Wochenschr* 2012; 137: 574–579.
  24. Narasimha S, Madathil KC, Agnisarman S, et al. Designing telemedicine systems for geriatric patients: a review of the usability studies. *Telemed J E Health* 2017; 23: 459–472.
  25. Flodgren G, Rachas A, Farmer AJ, et al. Interactive telemedicine: effects on professional practice and health care outcomes. *Cochrane Database Syst Rev* 2015; 7(9): Cd002098.
  26. Shah MN, Wasserman EB, Wang H, et al. High-intensity telemedicine decreases emergency department use by senior living community residents. *Telemed J E Health* 2016; 22: 251–258.
  27. Schofield RS, Kline SE, Schmalfuss CM, et al. Early outcomes of a care coordination-enhanced telehome care program for elderly veterans with chronic heart failure. *Telemed J E Health* 2005; 11: 20–27.
  28. Clark RA, Yallop JJ, Piterman L, et al. Adherence, adaptation and acceptance of elderly chronic heart failure patients to receiving healthcare via telephone-monitoring. *Eur J Heart Fail* 2007; 9: 1104–1111.
  29. Abdullah A, Liew SM, Hanafi NS, et al. What influences patients’ acceptance of a blood pressure telemonitoring service in primary care? A qualitative study. *Patient Prefer Adherence* 2016; 10: 99–106.
  30. Czaja SJ, Lee CC, Arana N, et al. Use of a telehealth system by older adults with hypertension. *J Telemed Telecare* 2014; 20: 184–191.
  31. Parker Oliver DR, Demiris G and Porock D. The usability of videophones for seniors and hospice providers: a brief report of two studies. *Comput Biol Med* 2005; 35: 782–790.
  32. Mehrabian S, Extra J, Wu YH, et al. The perceptions of cognitively impaired patients and their caregivers of a home telecare system. *Med Devices (Auckl)* 2015; 8: 21–29.
  33. McConnell T, Sturm T, Stevenson M, et al. Co-producing a shared understanding and definition of empowerment with people with dementia. *Res Involv Engagem* 2019; 5: 19.
  34. Wang G, Marradi C, Albayrak A, et al. Co-designing with people with dementia: a scoping review of involving people with dementia in design research. *Maturitas* 2019; 127: 55–63.
  35. Van Den Berg N, Schumann M, Kraft K, et al. Telemedicine and telecare for older patients – a systematic review. *Maturitas* 2012; 73: 94–114.
  36. Hui E, Woo J, Hjelm M, et al. Telemedicine: a pilot study in nursing home residents. *Gerontology* 2001; 47: 82–87.
  37. Foster A, Horspool KA, Edwards L, et al. Who does not participate in telehealth trials and why? A cross-sectional survey. *Trials* 2015; 16: 258.
  38. Stowe S and Harding S. Telecare, telehealth and telemedicine. *Eur Geriatr Med* 2010; 1: 193–197.
  39. Sanders C, Rogers A, Bowen R, et al. Exploring barriers to participation and adoption of telehealth and telecare within the whole system demonstrator trial: a qualitative study. *BMC Health Serv Res* 2012; 12: 220.
  40. Folstein M, Folstein S and McHugh P. ‘Mini-mental state’. A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975; 12: 189–198.
  41. Shulman KI, Pushkar Gold D, Cohen CA, et al. Clock-drawing and dementia in the community: a longitudinal study. *Int J Geriatr Psychiatry* 1993; 8: 487–496.
  42. Podsiadlo D and Richardson S. The timed ‘Up & Go’: a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991; 39: 142–148.
  43. Lawton MP and Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist* 1969; 9: 179–186.
  44. Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J Psychiatr Res* 1982; 17: 37–49.
  45. Tarlov AR, Ware JE Jr, Greenfield S, et al. The Medical Outcomes Study. An application of methods for monitoring the results of medical care. *JAMA* 1989; 262: 925–930.
  46. Rogers ES, Chamberlin J, Ellison ML, et al. A consumer-constructed scale to measure empowerment among users of mental health services. *Psychiatr Serv* 1997; 48: 1042–1047.
  47. Marc LG, Raue PJ and Bruce ML. Screening performance of the 15-item geriatric depression scale in a diverse elderly home care population. *Am J Geriatr Psychiatry* 2008; 16: 914–921.
  48. Morfeld M, Kirchberger I and Bullinger M. *SF-36 Fragebogen zum Gesundheitszustand: Deutsche Version des Short Form-36 Health Survey*. Göttingen, Germany: Hogrefe Verlag GmbH, 2011.
  49. Gelman A and Hill J. *Data analysis using regression and multilevel/hierarchical models*. Cambridge: Cambridge University Press, 2006.
  50. Gorst SL, Armitage CJ, Brownsell S, et al. Home telehealth uptake and continued use among heart failure and chronic obstructive pulmonary disease patients: a systematic review. *Ann Behav Med* 2014; 48: 323–336.
  51. Domingo M, Lupon J, González B, et al. Evaluation of a telemedicine system for heart failure patients: feasibility, acceptance rate, satisfaction and changes in patient behavior: results from the CARME (CAtalán Remote Management Evaluation) study. *Eur J Cardiovasc Nurs* 2012; 11: 410–418.

52. Subramanian U, Hopp F, Lowery J, et al. Research in home-care telemedicine: challenges in patient recruitment. *Telemed J E Health* 2004; 10: 155–161.
53. Edwards L, Thomas C, Gregory A, et al. Are people with chronic diseases interested in using telehealth? A cross-sectional postal survey. *J Med Internet Res* 2014; 16: e123.
54. Or CK and Karsh BT. A systematic review of patient acceptance of consumer health information technology. *J Am Med Inform Assoc* 2009; 16: 550–560.
55. Rahimpour M, Lovell NH, Celler BG, et al. Patients' perceptions of a home telecare system. *Int J Med Inform* 2008; 77: 486–498.
56. Lee PA, Greenfield G and Pappas Y. Patients' perception of using telehealth for type 2 diabetes management: a phenomenological study. *BMC Health Serv Res* 2018; 18: 549.
57. Gorst SL, Armitage C, Hawley M, et al. Exploring patient beliefs and perceptions about sustained use of telehealth. *Int J Integr Care* 2013; 13(7).
58. Fairbrother P, Ure J, Hanley J, et al. Telemonitoring for chronic heart failure: the views of patients and healthcare professionals – a qualitative study. *J Clin Nurs* 2014; 23: 132–144.
59. Narasimha S, Agnisarman S, Chalil Madathil K, et al. Designing home-based telemedicine systems for the geriatric population: an empirical study. *Telemed J E Health* 2018; 24: 94–110.
60. TÜV Rheinland im Auftrag des Bundesministeriums für Verkehr und digitale Infrastruktur. *Aktuelle Breitbandverfügbarkeit in Deutschland*. Berlin: Federal Ministry of Transport and Digital Infrastructure, 2018.
61. Zentralinstitut für die kassenärztliche Versorgung in der Bundesrepublik Deutschland. *Häufigste Diagnosen in Praxen von Allgemeinmedizinerinnen und -medizinern und praktischen Ärztinnen und Ärzten. Gesundheitsberichterstattung des Bundes*. Berlin: Zentralinstitut für die kassenärztliche Versorgung in der Bundesrepublik Deutschland, 2015.
62. Voigt K, Gottschall M, Lang C, et al. *Multimorbidität und Multimedikation. Der Hausarzt im alltäglichen Spannungsfeld der Priorisierung*. Dresden, Germany: Technische Universität Dresden, 2015.
63. Lang C, Scheibe M, Voigt K, et al. [Reasons for non-acceptance and non-use of a home telemonitoring application by multimorbid patients aged 65 years and over]. *Z Evid Fortbild Qual Gesundheitswes* 2019; 141–142: 76–88.
64. Inglis SC, Clark RA, McAlister FA, et al. Structured telephone support or telemonitoring programmes for patients with chronic heart failure. *Cochrane Database Syst Rev* 2010; (8): Cd007228.
65. Bortz J and Döring N. *Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler*. Heidelberg, Germany: Springer, 2006.

## Appendix



**Figure A1.** Estimated coefficients from a linear multilevel model of adherence, plotted different vital data (with 95% confidence interval).