‘That’s when I put it on’: stakeholder perspectives in large-scale remote health monitoring for older adults

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ORIGINAL PAPER

'That's when I put it on': stakeholder perspectives in large-scale remote health monitoring for older adults

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Abstract

Remote health monitoring (RHM) provides various benefits to older adults, but its use is still limited. Remote monitoring may help in avoiding emergencies and prolong users' independence. To understand how to design systems which support older adults, we studied a large-scale remote health monitoring system. The system used fitness-grade smartwatches to monitor the vital signs of more than 2000 users constantly. To probe the lived experience of using RHM, we conducted an explorative interview study ($N = 41$) with operators, carers, and users of the RHM system. Our thematic analysis reveals that personalisation of care ecology is crucial for developing users' confidence and trust in the system. We found that participation in RHM may catalyse positive changes in older adults' lifestyles. Based on our findings, we formulate five recommendations for designing future health monitoring systems. Our work contributes to insights into the lived experience and stakeholder ecology of health monitoring systems.

Keywords Older adults · Telehealth · Healthcare · Remote health monitoring · Wearables

1 Introduction

The rapid ageing of the population poses unprecedented challenges around the world. Governments and societies need to face the economic consequences of ageing [1, 2]. More importantly, we need to design ways in which the well-being of society can be maintained despite its increasing age. Research indicates that adapting to the changes which come with old age and understanding the limitations of our bodies is an effective way to increase the quality of life [3, 4]. Consequently, it is a challenge for Human-Computer Interaction (HCI) to understand the design of systems which can support older adults in adapting to the changing circumstances in their life.

HCI has an established record in designing and studying systems tailored for older adults. Past research efforts focused on designing engaging exercises to maintain physical activity [5] or fall detection [6]. A significant effort was directed towards understanding how personal informatics [7], i.e. the constant collection of personal data, could help older adults maintain their independence. Vargemidis et al. [8] conducted a review of wearable technologies for older adults and found that supervision was the most common design goal in such systems. Most systems offered a technocratic perspective and did not address user agency in supporting older adults. The review highlights a lack of understanding of how monitoring systems for older adults can foster independence and off increased quality of life. In order to achieve that goal, the HCI field must study how independence is achieved (or not) in the context of support systems for older adults. This paper is interestingly different from prior work, as it studies the living experience of various stakeholders of a large-scale remote health monitoring system in a year-long deployment. Instead of focusing on particular aspects of the monitoring experience (as studied by past research), we focus on a holistic cross-dimensional understanding of how users of monitoring systems interact with the devices and other stakeholders in the care ecosystem. We present a detailed, qualitative account which showcases the perspectives of older adults, professional care personnel (social workers), and informal on-site carers.

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To this end, we conducted an empirical study of the lived experience of a remote health monitoring (RHM) system for older adults. In contrast to past work, which focused on prototype systems and the design process of RHMs, e.g. [9, 10], we studied an existing RHM system provided to older adults by a municipality. This allowed us to investigate first-hand experiences of an RHM in action and build insights about the users' attitudes towards the system. We conducted Individual In-Depth Interview (IDI) with the target users of the system (older adults), remote carers, and on-site carers. Based on the gathered data, we constructed four themes which describe the lived experience of the RHM system: PERCEPTIONS OF FEAR AND SAFETY, RELATIONSHIPS WITH REMOTE CARERS, EVERYDAY ENCOUNTERS WITH RHM, and STAKEHOLDER ECOLOGY. Using the themes, we discuss the implications of our findings for future RHM.

Our work contributes: (1) a qualitative study of the lived experience of RHM, which includes data from $n = 41$ interviews with diverse stakeholders involved in the system; (2) four themes which offer a rich account of over a year of continuous RHM use; and (3) implications for designing future RHM systems. This paper is organised as follows. We first provide information on the context of the RHM system, which we studied. We then review past work which inspired and informed our inquiry. Next, we report on the method used to conduct interviews and present our findings in the form of four themes. Finally, we discuss how our results compare to past work and provide insights for future developments.

2 Background

In our inquiry, we study a large-scale remote health monitoring system that was introduced in a large city in Central Europe. The remote care project was introduced as a part of a new social policy of the municipality focused on supporting older residents (60+) and their families or carers. The project was implemented in a public-private partnership by the local authorities (City Hall), two NGO organisations and a business partner. The project was coordinated by the local government by the Department of Health and Social Affairs, which was responsible for participant recruitment and project promotion. Commercial partner supplied over 2000 volunteers recruited by City Hall with dedicated health bands and established an always-available remote support centre responsible for monitoring the users' vital signs and reacting to emergencies. Moreover, in case of a deterioration in health condition, the telecentre provides (1) arranging a doctor's appointment, (2) ordering medical transportation, and (3) providing information regarding the availability of pharmacies and healthcare facilities.

Local citizens could learn about the telecare project through various channels such as local press, medical centres, senior clubs, nursing homes, a dedicated website, social media, or word of mouth. All necessary recruitment forms were accessible in both digital and paper formats on the project website and at the City Hall. Individuals interested in participating in the project were required to submit completed recruitment documents to the city office in person or through an authorised representative. RHM users were recruited from local residents who volunteered for the project. The recruitment process aimed to secure a sufficient number of participants, resulting in 2000 applications. Once this limit was reached, subsequent applicants were placed on a reserve list. In the event of a participant's resignation from the main list, a replacement was selected from the reserve list to join the project. This approach ensured that the project maintained its intended number of participants throughout its duration. To qualify for the RHM project, one needed to be above 60 years old and must have lost independence in at least one of the key activities, as defined by the Barthel Index [11][1] The RHM project was subject to ethical scrutiny according to the regulations of the European Union for development projects. Preference was given to participants with disabilities and those who reported living in a single-person household. Participation in the project was free of charge for all users and preceded by a complimentary full health check procedure conducted by medical personnel.

The remote care system consisted of older adults using wearable devices (called 'the band' in the project) and a call-centre service facility available round-the-clock, seven days a week (the remote care centre). These elements were supported by the on-site carers, who were designated by the users from their close relatives or their long-term social care assistants. Medical and emergency services provided professional aid whenever necessary. Figure 1 presents the conceptual model of the system. We learnt from the project team that the key design goal of the system was supporting the cooperation between different stakeholders. While the architecture of the proposed solution focused on external monitoring by professional caretakers, the ecology of RHM required a proactive stance from all involved stakeholders. In particular, the older adults involved were to actively wear and maintain the tracking devices. Therefore, the presented systems blended the experiences of external monitoring with self-governed tracking. In our study, we examine a mixed scenario where user agency was necessary for external monitoring to operate successfully.

Users were equipped with dedicated health-monitoring wearable devices based on a custom fitness-grade smartwatch. Despite the smartwatch form factor, all stakeholders in the system consistently referred to the device as 'a

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[1] We note that the researchers involved in this paper had no influence on the selection criteria for the RHM project nor the ethical assessment thereof.

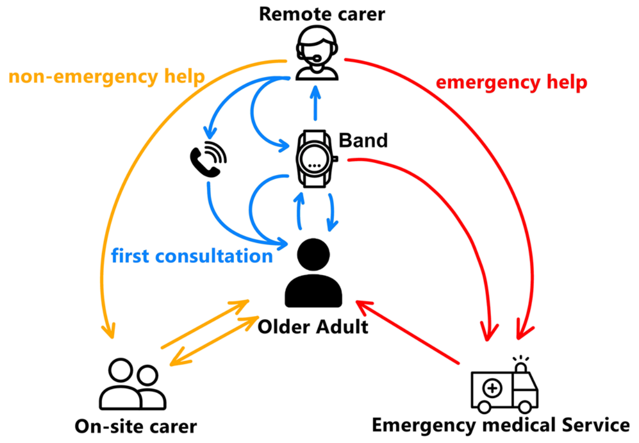

Fig. 1 System components and stakeholders in the RHM system which we studied. The figure represents ideal scenarios as communicated to us by the project team

band'. Therefore, for consistency and to align with the terminology used by the actors, we adopt the term 'band' in our paper, acknowledging that the physical appearance of the device resembles a smartwatch rather than a traditional wristband-based fitness tracker. The device constantly monitored the wearer's life parameters using optoelectronic sensors and logged the current location using GPS. The watch periodically shared the data with the care centre. Each band allowed making emergency calls and accepting calls from the remote carers thanks to installed individual GSM network SIM cards. An overview of the system functionalities are shown in Fig. 2. The band was equipped with an inertial sensor which enabled automatic fall detection. If the band detected that the wearer had fallen, it took a picture with a built-in camera and alerted the care centre, which responded with a phone call. The remote carers would then notify on-site carers and/or emergency services if necessary. The device transmitted all gathered personal data, i.e. (1) geographic coordinates, (2) heart rate, and (3) the number of steps, all with time stamp, to the care centre server, while the user had no access to or visibility of this information on the band's display. The display presented details like date, time, battery level, owner's name, and the SOS button. When an incoming voice call occurred, the interface provided options to either accept or reject the call. The project participants did not formally own the tracking devices. As part of the participation agreement, they signed contracts to rent the bands for the duration of the project, free of charge.

Each user received training in how to use the watch before they received it, and the remote health centre offered unlimited technical support. As part of the training process, users were thoroughly briefed on the watch's functionalities and the specific types of data collected from them. Additionally, each user received a comprehensive paper manual to reference at home.

The remote care centre employed a total of five pre-trained carers, who were responsible for monitoring the live data feed on participants' vital functions and responding to emergencies. The recruited personnel were trained in first-aid procedures (also remote aid) and had previous experience in customer service or as call operators. The centre operated a unified system that allowed live monitoring of participants' data (including historical records) and alerted the carers whenever help was requested, or the device recognised significant changes in the monitored parameters. The care centre had access to third-party medical consultation services, which supported the remote carers in analysing the participants' data. Prior to launching the system, the carers participated in a workshop with local emergency number operators, during which the system operation principles and example use scenarios were discussed.

Throughout this paper, we will refer to the health monitoring system and the stakeholders involved according to the following glossary:

- to the health monitoring system in its entirety as *health monitoring, RHM, telecare*, or *remote caretaking*
- to the users who participated in the project and were using the monitoring bands as *participants, users, older adults*, or *persons cared for*.

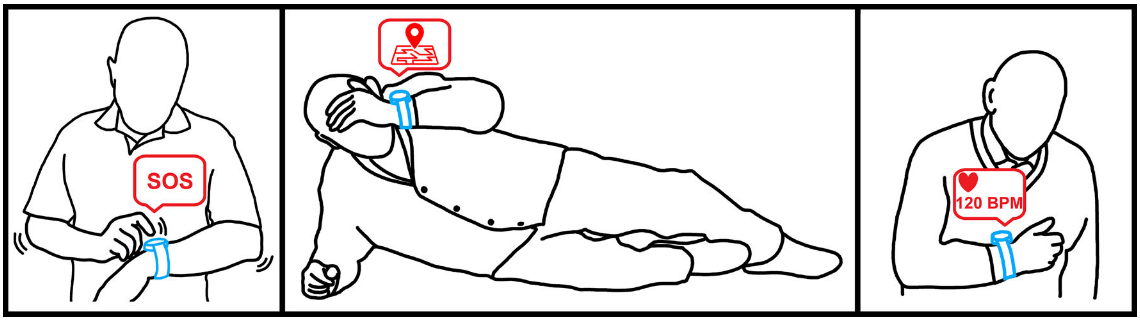

Fig. 2 An overview of the functionalities of the remote health monitoring system studied in our work. The smart band allowed the user to call for help (left), detected falls (middle), and alerted remote carers of elevated vital signs(right)

- to the monitoring centre and its facilities as the *(remote) care centre*, or *caretaking services*, and to its employees as the *remote carers*, or *telecarers*
- to the relatives of the participants designated as direct contact persons as *on-site carers*
- to the professional medical personnel, either emergency services or other aid, as *emergency or medical services/responders, emergency line*.

We continue to use a variety of terms to better reflect the language used by study participants (especially in excerpts and quotes) and preserve the latent meaning of particular statements [12].

This paper focuses on the lived experience of using a remote health monitoring system for 34 months. It is not the intention of the authors to assess the design or technological robustness of the wearable devices. Nor do we aim to judge the quality of the support provided. In our inquiry, we focus on the experiences of the stakeholders in the RHM system. Furthermore, we study if and how RHM supports a care ecology.

3 Related work

In this section, we establish the connection between our study and previous research on technologies for older adults. First, we present a broader overview of technologies targeting the ageing population, and subsequently, we delve into specific aspects related to RHM systems. Finally, we review works on collaboration between carers and persons cared for.

3.1 Health technologies for older adults

In the area of HCI, researchers have designed a wide range of technologies for older adults. A significant research direction was fostering physical activity in individuals with mobility impairment [8, 13]. These technologies included games for persons with Parkinson's disease [14], exergames for people in long-term care facilities [5] and systems to prevent falls and support rehabilitation [6].

More specifically, wearable devices have gained importance in recent years for supporting gait analysis, posture identification, and balance testing [15]. Such systems are often designed with older adults living independently as the target users [8]. However, reaching older populations has been challenging. Some technologies require accurate positioning on users' bodies while being unobtrusive to be accepted [16]. Such issues become even more severe when older adults are not involved in the design of technologies [17].

Previous work has identified a series of barriers that prevent the adoption of (self-)tracking technology. Older adults struggle with inaccurate sensors, battery/power issues, restricted monitoring areas/space and lack of interoperability [18]. Moreover, they prefer pen and paper for health data rather than devices such as computers and smart phones [19]. Often, the needs of older people do not match those of the younger generations that the technology was designed for [8]. For example, older users usually track steps and heart rate [20], while younger users track sleep and distance [21]. Moreover, chronic diseases might negatively impact user experience. Users with chronic illnesses might suffer from an augmented awareness of the disease and its effects, meaning that tracked symptoms or health indicators can remind them of their disease [22], thus evoking negative emotions [23]. When it is difficult to include older adults in the design process, caregivers are often involved as proxies, which might prioritise their perspective over those receiving the care, as seen in dementia care [24]. Most previous research has used focus groups and interviews with caregivers to elicit views of dementia patients on potential future technologies, such as smart homes. This has led to a debate focusing mainly on decontextualised principles of privacy and autonomy and researchers turning to creative methods, such as participatory design fiction [20].

Our work borrows its analytical lens from past studies of systems for older adults. Instead of designing a new system for research purposes, we study an industry-designed solution deployed on a large scale. This way, our study can empirically verify if the barriers and opportunities discussed in past research are encountered in the everyday practice of RHM.

3.2 Self-care and remote health monitoring of older adults

Ageing in place, i.e. preventing or delaying the need for older adults to live with a carer or in assisted living environments [8], is desired by approximately 90% of U.S. older adults [25]. However, age-related conditions or limitations often necessitate more frequent medical examinations and monitoring of one's health status. Robust, medical-class devices that perform complex and very accurate measurements are not always possible to employ at home because of environmental limitations, uncontrolled daily life routines and high acquisition and maintenance costs. Yet interestingly, even fragmented and incomplete data could be used for health monitoring purposes. Hence everyday well-being wearable monitoring devices are absolutely sufficient for most cases [26].

For monitoring older adults, daily community check-ins [10] and digital family portraits (for remote monitoring through family members) were among the technologies designed for ageing in place [27]. Also, 'smart home' technologies could provide emergency help, prevention and detection of falls and health data tracking [28]. On the other hand, studies on wearables allowing for calling for help in emergencies have shown ambivalent attitudes to it [29]. Users who perceived the system as unimportant did not use the call for help function even in crisis situations (falling and lying on the floor for up to an hour), while those who saw it as important were more willing to use the system for longer time [30].

However, monitoring behavioural, e.g. use of the shower, and physiological, e.g. heart rate, data can detect changes in the health and activity of older adults. Such data can be used to improve their quality of life and decrease hospitalisations [31]. Nevertheless, older adults may accept being monitored, even over long periods of time [32]. However, they want control over the means of data collection and its presentation to others [9].

In order to assess effectiveness and improve the design of health monitoring solutions, it is important to understand the use, misuse, and non-use of such systems [29]. So far, most evaluations have been short and used small samples [33], as they focused on the design qualities of the artefacts used for monitoring. A review by Vargemidis et al. [8] highlighted a need for more research on technology for independent older adults tested in real-world settings. These challenges can be addressed by studying how older people currently engage in self-tracking and identifying reasons that restrict technology adoption [34]. In this work, we contribute to the understanding of remote health monitoring systems (not allowing users to self-monitoring) and the attitudes and motivations associated with it by studying how older adults experienced RHM for over 2 years.

3.3 Data in care ecologies

The communication between the doctor and the patient is regarded as an area where self-tracking could contribute to ageing in place. Older adults should engage in self-care and receive care from professional caregivers, family, friends, and others [8]. Previously, specific aspects of care and self-care of older adults have been researched, but less focus has been put on the sociotechnical systems [8].

In regard to the communication between older adults and their caregivers, a common concern with in-home technologies is that they will replace human contact with formal and informal caregivers [35]. However, an exploratory in situ study revealed that an ecosystem of networked monitoring technologies did not negatively impact non-computer-mediated communication [36]. Caregivers sometimes take over the role of mediators for technology appropriation, e.g., when embedding technology in daily routines [37]. The success of such appropriation depends mainly on the added value perceived by their social care network. Caldeira et al. [38] found that the negative perceptions of becoming dependent on technology can be limited if the care-related processes are collaborative. A partnership between medical personnel and patients, focused on shared responsibility for the treatment, proved to convert to long-term improvement and enhanced medical adherence [39, 40].

The social advantages of health monitoring solutions, which enable both self-monitoring and remote monitoring, extend beyond enhancing communication between caregivers and users [41]. Intentional sharing of information about one's health may result in developing a more cognisant approach to the assessment of one's lifestyle [42] and motivate towards implementing healthy behaviour [43] for both the user and people in their environment [42]. If users have access to their data, tracking technologies are known to increase self-awareness, promote reflection over one's lifestyle [44], or aid in verifying falsely optimistic of one's health [45]. Collaborative analysis of health data within families proved to increase mutual trust and enhanced family members' engagement in caregiving [46]. Long-term awareness of a relative's state of health was considered crucial for informal caregivers to cope with everyday duties and maintain a caring and attentive approach [47], while also aiding their recovery from the eventual loss of a loved one [48].

Our work further investigates the social aspects of remote health monitoring in which users are only the source of the data and have no access to it. In particular, we aim to build a deeper understanding of how technology can help in building social relationships of care and coordinating carers' efforts.

4 Method

We conducted a qualitative inquiry to explore users' experiences with the RHM system. Through the partnership of local authorities and the first author's institution, the researchers gained access to an anonymised database of participants. The RHM project was subject to ethical and data protection scrutiny according to the regulations of the European Union for development projects. We decided to use interviews as they offered the opportunity to build a rich understanding of the experience of the system [49]. Moreover, given the sensitive nature of the collected data and the number of stakeholders involved, interviewing allowed us to limit sensitive data collection. Considering that the study was conducted during the COVID-19 pandemic, we applied a computer-assisted telephone interviewing protocol to limit the potential risks for the participants. Our investigations started with an unstructured interview conducted with the project coordinator. We used the insights gathered to inform the design of the semi-structured interviews with older adults, on-site carers, and remote carers.

4.1 Participants

Given the very large number of possible interviewees (the system had 2000 users; 1368 women−−68.4%, 632 men−−31.6%), we derived specific criteria for choosing the participants for our inquiry. Given the focus of our study (dynamics between stakeholders), it was crucial to specifically select system users who had telephone contact with telecare workers at least once. Through the initial expert interview, we discovered that each instance of an SOS signal activation was consistently met with a response from the care centre, initiating a subsequent telephone conversation with the user. Consequently, we opted to utilise the number of emergency reports (triggered by pressing the SOS alarm button) as an indicator of band usage and proof of interaction with the telecare centre. This measure allowed us to capture and assess the level of engagement and interaction with the device within the context of our research. A total of 169 users (8.5% of all project participants) initiated emergency signals, resulting in 343 alerts. Among these activations, 93 participants initiated the emergency signal once, while 76 participants activated it multiple times. The remote care centre categorised these alerts as ‘true’ (intentional usage—53 times) or ‘false’ (accidental usage or no need for intervention—290 times). This metric allowed us to choose a diverse sample of band users and recruit participants with different usage patterns. We set a minimum of 2 alarms to exclude RHM system users who forfeited using the device at the very beginning of the project.

The system lacked the capability to detect user-activated alarms that were not transmitted to the care centre. However, no reports were received regarding any lack of response from the care centre upon pressing the SOS button. We also did not recruit participants whose medical condition (e.g. senile dementia, Alzheimer’s) or disability (e.g. hearing impairment, speech and language disability, some mental illnesses) could make it impossible to conduct the interview procedure in a remote manner and/or without professional assistance. The participants were identified anonymously based on summary data stored in the RHM system. Before selecting participants, we obtained legal permission to access the data for research purposes according to local regulations.

We asked the remaining 76 users, fulfilling our criteria, if they would like to participate in the interview. Thirty-nine participants expressed interest in the study, and 5 users voluntarily withdrew from participation during the study. Finally, our work presents data from 34 interviews conducted with older adults ($N = 34$) ranging in age from 63 to 93 (avg. 79 years).

Table 1 presents a detailed list of the interviewed older adults.

The on-site carers were recruited using snowball sampling. We requested the users participating in the interviews to ask their carers if they would like to participate in the study. We reached a total of three on-site carers ($N = 3$), as presented in Table 2. We also invited all five remote carers employed by the remote care centre ($N = 4$), four of whom participated in our study (Table 2, right). System records indicate that the four recruited carers were, at one point, responsible for monitoring all of the users in the system.

All interviews were conducted, due to COVID-19 pandemic restrictions, via phone call with audio-only recording, upon receiving consent from participants. We decided to contact the users immediately once the project had finished, as we were interested in their opinions regarding the entire course of the remote care experience while not losing their immediate perception of using the device. Each participant received the local equivalent of USD 35 as remuneration for the interview. The compensation was determined based on interview duration estimates and calculated at a rate specified by the first author’s institution.

4.2 Interview protocol

We decided to start our inquiry by conducting an unstructured interview with one of the project coordinators, which enabled us to determine the precise scope of our inquiry [50] and planned further work. During the interview, we stimulated storytelling about the experiences and insights related to the coordinator’s role. The interview with the coordinator was not a part of the data set that we analysed because this person continues to be employed by the RHM provider, and revealing identifying characteristics and opinions about the system could deprive of anonymity and influence the work situation.

Based on the findings from the coordinator interview, we developed a semi-structured interview protocol for users of the bands and their on-site carers. We asked the participants to reflect retrospectively on their experience using the health monitoring bands and services of the remote care centre. We also prepared a semi-structured interview protocol for the remote carers. The open-ended design fostered storytelling and allowed exploring different perspectives of being a part of the remote care system.

We began each interview by reiterating the aim of the study and our data protection safeguards. Further, we informed the participants that they had the right to terminate the interview at any time without providing an explanation while still receiving their remuneration (five participants decided to end the interview prematurely). Due to the potentially intimate or sensitive nature of the interview topics, we emphasised that participants could disregard questions without explanation. To assure anonymity, we asked users to refrain from mentioning names during the interview. Therefore, the transcripts of the interviews did not contain any personal data. We applied

Table 1 An overview of the older adults (users) who participated in the interviews

PID	Gender	Age	Avg. HR	Illness reported
S1	Female	87	84	Thyroid disease
S2	Female	86	64	Diabetes, hypertension
S3	Female	87	76	Atrial fibrillation
S4	Female	83	86	Atrial fibrillation, Parkinson's disease
S5	Male	68	69	No major illnesses
S6	Female	81	68	Deafness, hypertension
S7	Female	81	88	Chemotherapy recovery, pressure spikes
S8	Female	82	86	Diabetes, atrial fibrillation
S9	Female	90	71	Diabetes, arrhythmia
S10	Female	76	72	Diabetes, cancer
S11	Female	90	75	No major illnesses
S12	Male	67	sys. mal	Asthma, diabetes
S13	Female	81	73	Frontal lobe aneurysm, deafness
S14	Male	83	62	Hypertension, diabetes
S15	Female	93	69	Hypertension, arthrosis
S16	Male	75	79	COPD, hypertension
S17	Female	77	76	Hypertension, diabetes
S18	Male	70	77	Hypotension
S19	Female	76	60	Rheumatic arthritis, hypertension
S20	Female	72	76	Post-trauma recovery
S21	Female	63	82	Osteoporosis, multiple sclerosis
S22	Male	72	71	Hypertension, cataracts
S23	Female	85	58	Asthma, hypertension
S24	Female	73	80	Hypotension
S25	Male	80	92	Hypertension
S26	Male	82	40	Aortic aneurysm
S27	Female	73	73	Hypertension
S28	Male	73	69	Hypertension, high cholesterol
S29	Female	75	75	Hypertension, arthrosis
S30	Female	83	65	Asthma, hypertension
S31	Female	90	84	Hypertension, degeneration of the spine
S32	Female	76	95	Asthma, hypertension
S33	Female	82	66	Arthritis, hypertension
S34	Female	75	72	Asthma, hypertension

The reported illnesses were extracted from the RHM database with the consent of the users

this protocol to all interviews, while topics mentioned during the interviews were altered between the users and the carers.

Our interviews with the older adults were focused mainly on probing their lived experience of long-term use of RHM and understanding their motivations to participate in the project. We invited the users to share their stories concerning the system and describe their routines with the bands. We were interested in understanding the social and psychological impact of participating in the project and how it influenced their lifestyles. We inquired about their communication with the remote carers and invited their reflections about the overall experience of long-term use of the system.

Talking to the on-site carers, we prompted them to discuss their efforts to provide care to their older relatives, and whenever the RHM system was featured in their stories, we inquired for more detail. We discussed their perceptions of the system and asked about their role within the system ecology. We also encouraged third-person views on how the person they cared for coped with using the system.

During the interviews with the remote carers, we were oriented towards reaching a deep understanding of their service. We investigated how they understood their role within the RHM system ecology, enquiring about their routines, protocols and approaches to supporting the users. We prompted

Table 2 Top: the on-site carers whom we recruited for our study

PID	Gender	Age	Person cared for
F1	Male	51	Female, 87 years
F2	Female	63	Female, 90 years
F3	Male	47	Female, 81 years

PID	Gender	Age
C1	Male	38
C2	Female	42
C3	Male	37
C4	Male	38

Note that we did not match the carers with users in our records to preserve anonymity. All on-site carers in our study were family members of the users. Social workers were also active within the RHM system, but they were unavailable due to work overload. Right: remote carers who participated in our study. They represent four out of five total employees of the care centre

them to tell us about the most frequent interventions and challenges they faced and probed their attitude towards older adults. We also discussed their perceptions of users' digital literacy and proficiency in using the bands.

The principal investigator, possessing a background in sociology, conducted the first unstructured interview with the project coordinator. Subsequent interviews were carried out by a qualified researcher who had received proper training and possessed prior experience in conducting similar research projects.

All interviews were conducted in the participant's native language, and for the paper, the transcriptions were translated into English.

4.3 Data analysis

The entire audio material recorded (total time 11 h 29 min) was transcribed verbatim. The resulting data corpus was analysed by three researchers, following the pragmatic approach to thematic analysis in line with Blandford et al. [51]. The researchers responsible for coding and analysing data were not involved in interviewing RHM users. The team comprised a principal investigator and two researchers who possessed extensive experience in conducting research projects.

We conducted an initial coding round using a flexible coding approach [52], where three coders open-coded the transcripts from eight interviews chosen at random and representing all three participant types. We used an inductive coding strategy to obtain an initial set of codes and constructed the coding trees. We then held a code adjustment session where the initial coding tree was discussed and distributed the remaining material among the three researchers. Having coded the entire data set, we held iterative discussions with axial coding, where we refined the final coding tree and identified common patterns in the data. Based on this analysis, we constructed four themes that describe the lived experience of the RHM system.

5 Findings

In this section, we present the findings of our inquiry, sharing the summary of participants' data and reporting the results of our thematic analysis, divided into four themes: Perceptions of fear and safety., Everyday Encounters with RHM, Relationships with Remote Carers and Stakeholder ecology (presented in Sects. 5.2, 5.3, 5.5, and 5.5, respectively). We illustrate our results using quotes from the interviews, marked with the participant IDs.

We organise the narrative of this section following the links in the users' perspective on adopting and using the RHM system. First, how long-term participation in RHM facilitated a shift in participants' sense of safety. Then, we reflect on the social context of living with RHM and how the technology impacted users' everyday life. We also analyse the bonds that developed between users and their remote carers. Finally, we contextualise these accounts, discussing the stakeholder ecology of providing round-the-clock health monitoring.

5.1 Insights from participants' monitoring data

To contextualise the qualitative findings and better understand users' behaviours concerning the devices, we analysed the summative data (overall sample of 2000 users) shared by the telecare centre. We looked at the numbers concerning the alarms triggered (flagged as true or false by the remote carers) to navigate the balance between emergencies and accidental use of bands' 'panic buttons'. We also looked at aggregated timestamps of the alerts triggered, which helped us understand the daily rhythm of participants and correlate it with accounts of using the band. The quantitative analysis was performed on a data sample (169 users) provided by telecare centre that contained but was not limited to, all participants of our interview study. Informed consent to share anonymised data of band measurements was a part of project participation rules. Table 3 contains detailed information on alerts and heart rates of respective participants.

The data on alerts triggered by the time of the day suggests that participants wore their bands throughout the day and continued using them during their evening routines (see Fig. 3). We spotted that most of the alerts were triggered in the afternoon and evening hours, which remains in line with users' accounts concerning the performed activities, especially those performed outside their place of residence. We suspect that increased alarm frequency in the evening hours originated in increased accidental use during evening

Table 3 An overview of users tracking data — SOS alerts triggered using the band and averaged heart rate

PID	False alerts	True alerts	Avg. HR
S1	8	3	84
S2	6	1	64
S3	5	0	76
S4	4	0	86
S5	4	0	69
S6	4	0	6
S7	2	1	88
S8	3	0	86
S9	2	0	71
S10	3	0	72
S11	3	0	75
S12	2	1	sys. mal
S13	3	0	73
S14	3	1	62
S15	3	1	69
S16	3	1	79
S17	3	0	76
S18	3	1	77
S19	3	1	60
S20	3	0	76
S21	2	1	82
S22	3	0	71
S23	2	0	58
S24	2	0	80
S25	1	1	92
S26	2	0	40
S27	2	0	73
S28	2	0	69
S29	1	1	75
S30	4	1	65
S31	4	1	84
S32	2	0	95
S33	2	0	66
S34	1	1	72

The validity of an SOS alert was differentiated based on the user's intent to trigger an alarm, as confirmed by remote caretakers. For S12, the heart rate data collected were deemed invalid due to the system malfunctioning

routines (which often concerned taking off the band, as mentioned in Everyday Encounters with RHM).

Remote caregivers consistently responded to all emergency signals, regardless of whether they were intentional calls for assistance or unintended activation. Through telephone conversations, remote caregivers effectively determined the intentional (true) or accidental or not needed (false) activation of the alarm. These findings highlight the commitment of remote caregivers to promptly address emergencies, despite the system's limitations in alarm detection and transmission.

Even though the participants expressed distress connected with triggering false alarms (see Everyday Encounters with RHM), these situations were infrequent for respective participants concerning the duration of the telecare project. A vast majority of older adults triggered no more than three emergency alerts throughout the project (see Fig. 3). These observations suggest that reaching emergency help using the band was a meaningful experience and that users considered it a serious mean of alarming others about their condition.

5.2 Perceptions of fear and safety

Our interview data indicated that the most frequent motivation to join the telecare project was users' apprehension about their ability to cope in emergencies. Participants reported that considering their overall medical condition, they experienced fear regarding potentially fatal events that could occur when they were alone. Fear about being left alone in case of emergency was especially notable among those older adults, who lived in a single-person household, suffered from chronic diseases, or had disabilities. Participants noticed that their daily life was affected due to health-related constraints:

> For me, safety is first and foremost. Well, you know, I am old, and on top of that, I have these accompanying diseases - diabetes and hypertension. And with this amputation [...] I could fall over at any time; it could happen at any moment, and no one might notice. (S18)

Another frequent viewpoint considered changes in the health and lifestyle of older adults. Participants reflected that at a certain age, one should live more carefully and acknowledge the increased exposure to possible danger.

> Well, we're older [...] elderly and sick people. I tend to get injured easily. (S13)

We encouraged the participants to reflect on the benefits resulting from the everyday use of RHM. Our interviewees recognised that wearing the monitoring band contributed to their confidence and alleviated the fear of being left alone in case of an emergency. Many older adults noted that the traditional ways of requesting help (e.g. making a phone call) might have been too challenging or beyond their physical capabilities:

> I knew there was someone out there [...] someone who would receive the signal, who would contact me, who would send help. (S34)

Throughout the monitoring period, the carers responded to a number of emergencies that required immediate help from either the on-site carer or medical personnel. The 'panic button' feature was deemed life-saving in these situations, as

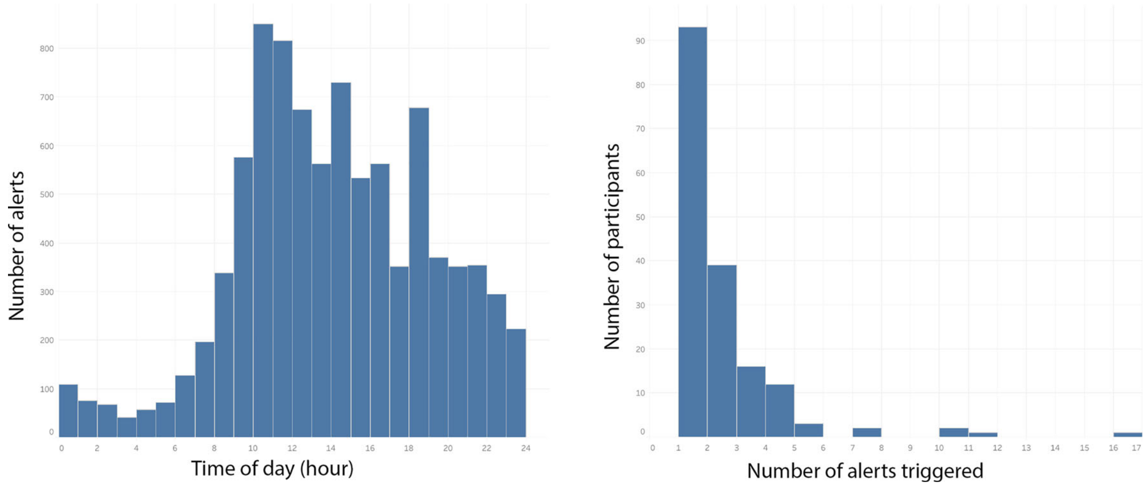

Fig. 3 Histogram of alerts triggered by the participants ($N = 169$) at respective times of a day (left), and analysis of the number of alerts triggered by the older adults (right). The distribution remains in line with user accounts on their daily schedules and activities. The majority of users triggered no more than three alerts throughout their participation in the care project

participants reported that using alternative ways to call for help would have been impossible:

> It's because this watch saved my life twice. I have diabetes, and I often experience drops in sugar levels. I had a significant drop in sugar twice while I was in the city. I connected with the helper through this watch before I took the phone out [...] I just didn't have the strength anymore, and I wouldn't have been able to call anyone. This has happened to me twice. [...] The ambulance arrived immediately, and the telecarer called.(S8)

Interestingly, the care centre classified both mentioned alerts as false alarms. The data on the alarms triggered (see Table 3) depict that triggering false alarms was a recurring issue. Participants mentioned that they inadvertently requested help when casually touching the device to ensure its correct operation. Triggering false alarms was considered a significant issue, as 290 out of 343 (84,5%) logged SOS alerts were triggered unintentionally.

> He called me, this man from the care centre, and asked if everything was OK, I was a bit confused, but he told me that I pushed the button, but I didn't do it. At least not intentionally. (S12)

While the remote carers applied their standard procedure, triggering a false alarm was a source of distress or guilt for many older adults.

We also discovered that being constantly monitored affected people beyond the users themselves. S27 reported that being equipped with her personal 'panic button' affected her relationships with neighbours. The user claimed that she had been afraid of some of her neighbours, who often caused a nuisance in the building, and eventually informed them that she was equipped with such a device, which resulted in more restrained behaviour towards her.

> Here, where I live, we have problematic neighbours. They knew about these bands, that the alarm would go on and alert someone if they tried something [...] This band defended me, and they were afraid [...] otherwise, nobody knows what could have happened to me. (S27)

This indicates that users viewed RHM as a safety measure, akin to a 'panic button', for both medical and non-medical situations.

Users reported that wearing the band also encouraged them to engage in hobbies and live a more active lifestyle. Some participants reflected that being subject to RHM had encouraged them to engage in a more vibrant social life or to overcome the fear of leaving home. Two users directly indicated that wearing the band had a positive psychological impact on them. The ability to easily obtain immediate, on-site help, regardless of their location or activity, was praised as a key feature that contributed to their perceived safety.

> I ride a bike a bit. Whenever I did, I always wore this watch because, in the event of a fall, I knew it could help me. There would be an immediate reaction, and help would be called. It's in these situations that I always put it on, specifically for biking. (S5)

5.3 Everyday encounters with RHM

Within this theme, we present our observations on how older adults experienced the everyday use of RHM bands. We probed their perceptions and enquired about their understanding of the system's operation.

In the early phase of the project, all users were instructed that the bands provided round-the-clock tracking and were advised to wear them for most of the day. Selected participants whose medical condition suggested that it would be advisable to monitor them at night (e.g. those affected by sleep apnea) were advised to keep the device on at night and schedule charging procedures during the day. However, only a few users adhered to these instructions. Many users wore the devices only in contexts which they considered potentially dangerous. The majority of the older adults in the study reported that they took off their bands for sleeping and hygiene routines, as they avoided wetting the device or found it inconvenient. We also observed that a large group of older adults had worn the bands only while leaving their homes, reflecting their habits of wearing a watch.

> Well, when I went to sleep, I put it on the table. You know, because I did not sleep in it, and so there was no need to wear it. When we went out with my wife, we put it on, while at home, it just lay on the table. (S14)

Among those who wore the device at all times, they emphasised the ability to call for help at all times. The carers monitored participants' vital functions and reacted with a check-up call if the data logged were considered suspicious or unusual. However, in order not to scare the users, they did not always reveal that they had been alerted but rather inquired about the person's overall well-being. These calls were perceived as caring and motivating and built a feeling that someone was looking out for them.

The ability to immediately call for help was considered important and desirable by the users. However, they were worried about rising false alarms. For some of them, triggering false calls was so frequent that it led to frustration and eventually deciding to limit using the band. Other participants noticed that the device performed the measurements in fixed intervals and notified them using light indicators. Consequently, if they spotted that an unworn band was shining, they would put it on for a moment, just to discard it again when the lights went off.

Participants shared diverging views concerning the fall detection functionality, where the watch took a photo whenever a fall was detected. The feature was warmly received by the users who had frequently referred to their comments about limited mobility. However, the awareness of the device being able to photograph them led to more careful usage in certain contexts. Individual participants noticed that the device indicated that it had taken a photo with a blue light indicator:

> So, you know, I noticed that this blue light indicates that it took a photo of me, whether I had fallen or if something was wrong with me [...] since then I stopped undressing in my room, I left the watch on the table and went to the bathroom to undress. Mother of God, possibly someone had seen what I was doing. (S23)

The concern about privacy violations and the device photographing users was also reported to affect people beyond the users themselves. One of the participants recalled a situation where the presence of the device persuaded her relatives to alter their behaviour as they felt discomfort.

> I was at a birthday party [...] and the older gentlemen sat at the table and wanted to drink together [...] and my watch was shining, sometimes green, sometimes blue, and I explained that it shines blue when it takes a photo. [...] and these elegant gentlemen, they went away, and later on, I deduced that what scared them off were these lights of mine. (S23)

According to project data, abandonment of the monitoring devices was a major issue in the system's operation. We probed the reasons for rejecting using the system regularly and reached a number of various responses. One of the most frequent arguments originated with a misunderstanding of the principles of band operation, which led to conclusions about it being either faulty or useless. Missing feedback from the device was deemed especially misleading - users claimed that the band measured neither the heart rate nor the temperature, as the results were not displayed. It demonstrates the need for thorough user training to leave no room for speculation and doubts regarding device functioning. Moreover, we revealed that the role of the remote care centre was considered confusing, and the monitoring features were insufficiently explained. As a result, the older adults treated the band as a fancy version of a 'panic button' and were unwilling to wear it on a daily basis.

> I wore it for a couple of days, and then I stopped because it wasn't helpful. It doesn't measure the heart rate, the blood pressure [...] It is just a watch that, in case of a sudden danger, I can press it, and the paramedics would come to the place where I was. That's what my son told me, how he explained it. (S26)

The carers reported that a significant number of older adults were afraid to use the devices unassisted. They claimed that they were either unwilling to learn how to use new technology as they considered it tiring or felt ashamed to ask for assistance with device operation. Some participants quit using the device as they found it irritating to charge it every couple of hours (which problem was alleviated by the technical support during the course of the project). One of the carers noted that users were scared of possible fees in case a device got destroyed, even though the project rules waived any user responsibility for its condition.

The older adults who were usung teh system extensively were happy to share their stories with friends and family. Users reported they had discussed the technology with relatives and had invited their peers to inquire about the possibility of obtaining similar devices for themselves. They also reported that the personnel who trained them in using the band had assessed that the majority of users felt proud and technologically competent, once they completed the training.

We witnessed that using the RHM was not only helpful but became a topic of casual conversations with users' acquaintances. Wearing the band drew the attention of their peers:

> When I went to swimming classes, people asked me about this watch, what it does, and where to get one. I felt modern wearing it. (S4)

Participation in telecare was considered a form of distinction in the eyes of other older adults and made them interested in the possibility of joining the project themselves.

5.4 Relationships with remote carers

In the preceding sections, it is well apparent how participation in the project has contributed to an improved sense of safety and building users' confidence. One of the important reasons for this was the bonds between users and remote carers that developed throughout using the system. Within this theme, we show the characteristics of mutual communication. We report on both the participant's and carer's perspectives on how mutual contact was realised.

Throughout the project, the remote care centre not only responded to alerts from the system but also served as a general help hotline for the users. The remote carers reported that the majority of incoming calls had concerned organisational and technical issues. The centre was treated as a help desk for maintenance and configuring the device. Multiple calls concerned recurring issues with the band's connection to the server:

> Overall, most often, the older adults called with technical issues, problems with the band [...], such as how to charge the battery or when the display was off for some time, and they needed instructions on how to turn it back on. (C4)

Numerous users were hesitant to contact the care centre as they felt ashamed of their inability to operate the device. The carers observed that many of them were apologetic for occupying their time and embarrassed about not being computer-savvy. On the other hand, the users expressed that they were satisfied with the quality of technical support, felt confident that their problem would be solved and were pleased with the politeness and patience of their interlocutors:

> Whenever I didn't know something, or when I read the leaflet and was unsure, I could have called them. There were technical people to help me, and a very polite gentleman picked up and explained everything. (S30)

However, the majority of the communication between users and the centre was initiated by the remote carers, based on the data reports and alerts received. Whenever the vital function measurements were considered unusual, the carers tried to reach the participant either using the band call or via phone. However, a significant share of these calls were reactions to false alarms, triggered accidentally or related to dropping the band. The carers reported that users often felt guilty or ashamed when called.

> If it were that they had accidentally pressed the SOS button, and we responded to verify the alarm, they were usually bashful and apologetic. However, whenever the trigger was intentional, or they really felt worse at that time, they were very pleased we reacted so quickly. (C1)

The majority of older adults spoke very highly of the quality of service provided by remote carers. Beyond the enhanced feeling of being cared for, the participants appreciated the patience and proactive approach of the carers. The users were pleased that the remote carers not only reacted to direct alerts but also inquired after resolving a case:

> They came to stabilise my blood sugar levels [...], I felt better, and before I reached home, as I did not agree to go to the hospital, that telecare guy called me several times to check up on me. (S8)

The proactive and caring approach was highlighted by the carers as a crucial element of their work. They noted that the service they provided reached beyond emergency response and also benefited the mental well-being of the older adults. Therefore, they eagerly engaged in off-topic discussions, as they recognised their role in maintaining the overall experience of being cared for. Since the carers had significant freedom in shaping those conversations, their caring attitude was expressed in the way in which they conducted discourse:

> All these off-topic chats and prolonged conversations were conducted because we, as a team, pay attention to how these older adults feel about this entire system. We want them to feel welcome to call us with any problem they face and not feel like intruders who just call and bother us. (C3)

This approach resulted in developing bonds between the users and the carers. When asked about their experience, the older adults referred to them as their 'guardian angels' or compared them to their close relatives. Users praised their politeness, understanding and patience, which reached beyond assessing the current health state of the user. The remote carers reported that participants eagerly shared their everyday life stories and were engaged in keeping in touch with them.

> They were really glad that there was someone looking out for them. Some of them called us their 'guardian angels'. (C2)

A few participants developed bonds with individual carers and called the centre requesting to talk to a particular person. Some of them were eager to postpone the call if that person was not on duty. Furthermore, the carers considered themselves successful in resolving conflicts whenever a dissatisfied user contacted them. They employed a strategy based on acceptance of all reactions and explaining the common goal of the users' well-being.

The remote carers were also responsible for contacting the on-site carers whenever direct assistance was deemed necessary or when they could not reach the user. The older adults appreciated the cooperation of the remote care centre with their relatives. Several participants experienced a situation where the carers reached their children or neighbours, who visited them shortly afterwards at their homes. These experiences built the users' confidence that the system was capable of converting monitoring into direct assistance whenever necessary:

> My daughter called me, as someone notified her. (...) It was the remote care people who called her, and they wanted to know where I was, if I needed help, what was going on. (...) It was really pleasing that I had a device, and it worked bad thing actually happened... (S28)

5.5 Stakeholder ecology

The last part focuses on challenges that the remote care centre had to face in terms of cooperation with on-site carers and emergency services.

The users were instructed that the RHM system would enable them to request medical assistance quickly and easily. However, the emergency line operators did not have access to users' location data, which led to confusion. The remote carers reported that the emergency services were insufficiently informed in the early stages of the project. Users would refer to the band when contacting emergency services, assuming the data would be available to the emergency operator. Our interviewees reported that, initially, first responders were reluctant to cooperate with the remote care centre due to it not being a public institution:

> Sometimes we called the older adults, but they weren't able to tell us if the emergency services had confirmed their alert. So, we called them ourselves to verify if an ambulance had been sent to this particular person. (C2)

The remote carers monitored the situation closely in cases of emergency. It was common practice to call the older adult on the phone while the person was talking to the emergency services via the band to assist in the conversation. Triggering false alarms was considered a significant issue, as 290 out of 343 (84,5%) logged SOS alerts were triggered unintentionally or were analysed as not needed. Both users and remote carers emphasised that access to localisation data was especially useful in emergencies. The older adults noted that it would be difficult to provide a precise location when in an unknown area, while the carers praised the ability to react right away, regardless of the user's health condition. Live location was valuable whenever the participant did not sufficiently inform their relatives about their whereabouts. In such cases, the operators reached the users through the band or provided their location to the on-site carers for verification:

> We had such interventions where the on-site carers called us because the user had gone somewhere, and they could not reach them. So we tried to call the band, and if it didn't help, we got the GPS location and provided it to the carer so that they could find the person. So this was useful sometimes too. (C4)

Cooperation with the on-site carers proved crucial in verifying alarms raised by the participants. While the emergency services applied their standard procedure and dismissed the call if it was triggered accidentally, this information did not necessarily was communicated back to the remote care centre. If the remote carers could not reach the user, they contacted the on-site carers to request their help. The relatives were also consulted once the centre noted that the older adult required medical attention - in such cases, the remote carers followed up for updates on their condition.

6 Discussion

Here, we reflect on our findings and discuss the implications of our work for future RHM. We contribute five recommendations for future systems. The short versions of these recommendations are *highlighted in italics*.

6.1 The RHM created a feeling of safety, trust and care through personal communication

In the PERCEPTIONS OF FEAR AND SAFETY theme, we observed how the RHM system provided additional safety in the lives of its users. Participants reported engaging in new activities or being less afraid to perform certain actions. In this way, it appears that the system did fulfil its primary goal of increasing user agency [8]. Interestingly, most users reported that they did not feel supervised, but rather they could rely on the help of the carer when they needed it. We hypothesise that this effect can be partly attributed to the 'sensitivity' of the RHM system—the band was designed to err on the side of caution and triggered many alarms. These alarms not only alerted the care centre to emergencies but also led to personal contact with the remote carers (RELATIONSHIPS WITH REMOTE CARERS). Despite instances where participants accidentally or unknowingly triggered alarms and felt embarrassed while speaking to the telecaretaker, the reassurance of having someone watching over them outweighed the negative emotions. For older adults, the sense of safety is paramount, and even in the occurrence of false alarms, using the system remained satisfying for the participants. Previous work has shown that when users perceive emergency response systems as relevant, they use them more frequently in emergency situations [30]. We believe that exploring the use of the SOS button for other non-medical emergencies, such as situations involving threats from third parties, could be valuable, as the sense of safety experienced by older adults extends beyond health-related factors alone. In further research, it would be essential to define the specific situations in which users would find the use of such an SOS function desirable and how this feature should operate, including the emergency contact number it should connect to. Additionally, it would be crucial to determine how to prevent excessive or unintentional use of the SOS function for non-medical purposes.

We argue that the feeling of reliability projected onto the RHM system might also result in increased usage. However, future work needs to investigate this link between perceived reliability, perceived relevance and usage in more detail. Further investigation is warranted to determine the mode of action of the camera in the band, particularly in light of multiple cases when participants reported privacy concerns related to that functionality. Consequently, our work suggests that *using staffed remote care centres in RHM systems not only allows for efficient data processing but also contributes to fostering a feeling of safety in the older adults*.

6.2 The RHM was a good fit for users with a developed care ecology

Our findings in the RELATIONSHIPS WITH REMOTE CARERS and STAKEHOLDER ECOLOGY themes showed how the match between the perceived structure of care around the user and the design of the band was important for a positive monitoring experience. Older adults who experienced the collaboration between on-site and remote carers reported satisfaction with the monitoring system. Consequently, future systems for RHM should *include a wide range of stakeholders who contribute to care*. The functionalities of the monitoring system need to be transparent and available to all stakeholders potentially providing care. This finding raises further questions in terms of who should be involved in an optimal care ecology and how communication among carers can be supported by technology, cf. [24].

6.3 The band was a precious artefact

In their EVERYDAY ENCOUNTERS WITH RHM system, the older adults in our study were often concerned with the possibility of damaging the band. They desired to be responsible, wearing and maintaining the device as required. We even observed cases where band usage was discontinued due to some participants being afraid to break the monitoring device. Such occurrences are relatively common within the context of perceiving wearable devices perceived as expensive. This suggests that wearable RHM could take alternative design directions.

On the one hand, past work assumed that health monitoring should become unnoticeable and only be brought to attention when required [53, 54]. In such an approach, qualities like non-intrusiveness and durability are highly valued. On the other, our work suggests that *a health monitoring device could be designed to be a cherished object* [55]. In our study, older adults were proud to have their bands and satisfied that they could care for them as required. Possessing them was a source of pride in social contexts, which improved their psychological well-being. Moreover, our work suggests that an RHM device that the wearer treasures can contribute to a perception of agency.

These two conceptions can be successfully aligned, as creating engaging experiences is considered an essential part of the 'calm computing' paradigm [56], which can also be leveraged for ubiquitous wearable devices. However, we assess that the described RHM system required excessive user attention and maintenance, making the longitudinal experience cumbersome, as depicted in Sect. 5.3.

Hence, it is crucial to strike a balance in the design to ensure that users find the band appealing while also feeling comfortable and encouraged to utilise it. Subsequently, further research will help to formulate comprehensive design guidelines that effectively consider and reconcile this inherent dichotomy, ensuring an optimal user experience.

6.4 The RHM system affected activities beyond health

Receiving a health monitoring band was not only perceived as a health intervention but also affected other aspects of the users' lives. In RELATIONSHIPS WITH REMOTE CARERS, we observed how the system facilitated serendipitous encounters with remote carers and led to the development of new social bonds. Previously, [36] reported that in-home technologies did not reduce non-computer-mediated communication. We extend this claim and argue that the RHM system might even improve communication between users and caregivers. The EVERYDAY ENCOUNTERS WITH RHM theme described how the band enabled more active routines but also elicited privacy-related behaviours. While previous work described concerns about privacy as less common in older adults [57], others suggested that this might change with continued use when a more nuanced understanding of the privacy implications emerges [36]. Through our research, we have noted that a caring-focused system can sometimes become overly protective, resulting in a negative impact on users' sense of privacy. The inclusion of a built-in camera in the band can give users a feeling of being observed rather than simply monitored in terms of health parameters, which is not appropriate. When users do not feel comfortable in their own homes, they may choose to discontinue using the band, ultimately leading to the system's inability to provide adequate help for the user. These findings suggest that future monitoring systems for older adults should be designed *not only with physical health as a design goal*. While traditional systems focused on assistance in emergencies, e.g [6], there is potential for RHM to contribute to the overall quality of life of users, as suggested by [31].

6.5 Programmatic thinking is required for socially responsible RHM systems

A project-specific caveat that we observed in our study was that the RHM system was deployed for a specified period of 2 years. Throughout the project, users developed a relationship with the carers and the bands became cherished objects. Most importantly, the deployment led to the establishment of a functional care ecology. In particular, we observed that the way in which emergency services transitioned to actively using the system (STAKEHOLDER ECOLOGY) showed that the technology only allowed for more effective care after an initial transition period. These facts highlight that the *RHM systems can only be responsibly deployed as open-ended projects*. This finding echoes past critiques of one-off prototype developments [8, 33] and confirms it based on long-term usage experiences.

6.6 Limitations

We recognise that our inquiry is prone to certain limitations. First, we recognise that we made a decision to engage with users who used the RHM system and had contact with the care centre at least once. This implies that we inherently report primarily specific scenarios of using the system. While identifying positive design qualities in an RHM system can contribute to improving future systems, researching stories of abandonment is of equal importance. In our particular case, many of the users had abandoned the system in its early phases more than a year before our study. Consequently, our access to accounts of abandonment was limited. Second, considering the number of study participants, we acknowledge there is an interconnected network of challenges related to building trust among different stakeholders of the RHM system, and the technology itself. Furthermore, we cannot underestimate the cultural factor in the perceptions of the system studied in this paper. The participants were limited to a particular geographical area, and all resided in a city. We expect that the experiences may have been different in, for instance, rural communities. While we attempted to recruit a diverse participant sample, we see a need for future research to study the long-term experiences of RHM across communities. A theme worth looking at for the future is the characteristics of the stakeholders involved in RHM systems. With increasing life expectancy, healthy life expectancy and changing proportions between working-age and post-working-age populations, we will see more and more scenarios where the caregivers of the older adults will be other older people. This trend is culturally determined, and we did not see signs of it in this study, but it can be expected to increase in the future. Finally, we note that we decided to take an objective approach to study the RHM system by conducting our work at the end of the project, resulting in a summative evaluation of the solution. Future studies should also consider a formative approach where researchers would gather data throughout the development and deployment of the RHM system.

7 Conclusion

In this paper, we reported on a study that investigated the long-term use of an RHM system. We conducted interviews with the users, remote carers and on-site carers. Our results showed that the system produced a feeling of safety in the users. Care ecologies and communication were of particular importance to the success of the system. Based on our findings, we suggest that future RHM systems should enable trust through communication, support care ecologies, allow for tracking devices to become cherished objects, span activities beyond health, and be designed for long-term maintenance. We hope that our work inspires further developments in understanding the opportunities and challenges of RHM.

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Data availability The RHM quantitative datasets analysed in the current study are not publicly available as the researchers are neither the owners nor data administrators. They only had limited access to the data to conduct the inquiry. However, the associated data from in-depth interviews (IDI) is available in a data repository.

Declarations

Competing interests The authors declare no competing interests.

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