

Accounting for Medication Particularities

Designing for Everyday Medication Management

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Abstract— Several projects have shown that self-management of medication in private homes can be challenging. Many projects focused on specific illness-related approaches (e.g. diabetes) or practical issues such as how to handle medication while travelling. However, designing for everyday medication management involves more than just specific illness-related strategies and should take into account the broad set of activities conforming people’s everyday life. This study investigates how older adults manage their medication in everyday life. To inform the design of pervasive healthcare medication management systems (PHMMS), the study calls for attention to medication-specific particularities that account for: according to need medication, the heterogeneous care network, the substitute medication, the medication informational order, the shared responsibility and the adjustment of medication intake. These medication particularities can enhance the individual’s medication overview and support the understanding of medication intake in everyday life. The study also presents five design principles for future design of PHMMS.

Keywords- *Medication management; Qualitative; Quantitative; Personalized; User-centered Design; Older Adults.*

I. INTRODUCTION

Older adults who live independently in their private homes are often responsible for their own daily medication intake. Based on an iterative, user-centered project, and qualitative and quantitative studies this paper discusses how older adults manage their medication outside of clinical settings, such as private homes. Taking into account how medication-specific requirements can inform support systems for everyday medication intake and administration, this paper presents design principles to consider when designing such systems for older adults’ homes and everyday lives.

The target group for our project is older adults who are able to manage their medication at the moment but might need assistance in the future. To illustrate challenges in everyday medication management for older adults, we now present a scenario based on a collection of experiences derived from our user studies:

Ann is 73 years old; she lives alone since her husband died two years ago. She suffers from a range of illnesses including diabetes, osteoporosis, back pain and hypertension. As a result, she takes up to 19 medications a day, spread evenly throughout the day. Indeed, Ann finds it hard to remember to buy new

medications as all packages contain different amounts of medication and so it happens that she runs out of medication. Another challenge for Ann is when the pharmacy substitutes her medication, due to a cheaper price. Ann likes the cheaper price, but the new medication’s name sometimes confuses her.

Ann takes great pride in going to the local elderly center to follow their activities, including bingo events and ‘eat togethers’. Her son Thomas lives in the same town and he, and her two grandchildren, visit her every second week. When home alone, Ann usually remembers to take her medication. However, when Thomas and the grandchildren visit her, she tends to forget her pills during their stay. When Thomas cooks for her, he usually cooks very differently from what Ann usually does and she knows that she has to pay attention to what she eats with some of her medication. Ann really doesn’t know what to do when she forgets a dosage of medication, sometimes she takes a double dose at the next scheduled time and sometimes she just skips it. She has planned to speak with her doctor about this, but when at the clinic she never remembers to ask. Furthermore, Ann’s doctor is not aware that Ann does not take her hypertension medication once in a while when she visits her neighbor for evening tea. Overall, Ann has problems taking the medication when her routines are broken, for example when she stays a bit longer than planned at the elderly center, or when she has visits or visits friends.

This scenario identifies the following key challenges in Ann’s daily medication management: forgetting to buy and take medication, the breakdown of routines, the lack of medication information at hand, handling substitution medication and her doctor’s lack of insight in her medication adherence. These challenges are discussed in this paper.

That people (of all age groups) forget their medication and the amount of medication that they have to take are common causes to non-adherence to a prescribed regimen [1]. It might sound trivial, but in our study we have encountered older adults taking up to 35 pills a day. To sustain a correct medication regimen is even more complex when prescription medication also includes for example creams, injections and eye drops. According to the World Health Organization (WHO) [2] common reasons why people do not comply with a prescribed medication regimen are for example forgetfulness, deliberately not following the prescription, not being able to handle the number of medications, fear of side effects and problems

interpreting the instructions on how to take the medication. This non-adherence is connected with large costs for both the individual and society [3].

In the following, we present related work and our user studies. We then report on findings that provide insights for the design of future pervasive healthcare medication management systems (PHMMS), and discuss particularities of medication management that have not previously been discussed as a whole. The findings call for designing a PHMMS for non-clinical use that not only supports monitoring and reminders, but also provide individualized support facilitating for example the individual's understanding of, and reason for, medication intake. A desired effect is to move away from compliance and adherence and move towards concordance [4] through a dialogue with the healthcare professionals. Finally, we extract five design principles for the design of PHMMS to support older adults' everyday life and their medication needs. These design principles are directly related to the key challenges exemplified in the scenario above based on our user studies.

II. RELATED WORK

This section reports on the medication process and technologies as strategies for medication management. We also describe known design principles for medication management and previous work on patient-healthcare collaboration.

A. The Medication Process

Medication intake and administration is a complicated endeavor. In a clinical setting, a prescribed medication is measured, administered, evaluated and adjusted by healthcare professionals [5]. Through for example mobile technology, healthcare professionals can be supported in their medication administration routines [6]. Indeed, in order to improve care coordination, physicians have used cognitive artifacts to support local awareness of patients [7] and nursing notes to generate the patients' medication overviews [5]. People in non-clinical settings are however expected to engage in self-care activities such as self-diagnosis, self-management, self-medication and self-monitoring [8]. A supported medication self-management can facilitate *the move across boundaries* (e.g. when an individual moves between the clinic (i.e. being a patient) and the home (being a parent or spouse)) to defeat identified physical, psychological, cognitive, economic, social and cultural barriers found in self-care [9]. Today people use diverse strategies to support their home-based medication regimen such as: reminders, tablet-holders, dosing aid, automatic dispensers, software applications, pill boxes (with or without technology), and paper-based medication lists [10].

B. Technologies and Strategies for Medication Management

A mix of sensor and self-reporting techniques have been investigated to support people with diabetes [11, 12]. Studies have shown that medication management routines are highly personal, and non-frequent activities such as travelling that challenge established routines [11, 13]. Palen and Aaløkke [14] argue that individual strategies and routines can support people to integrate medications into their everyday lives. However, these strategies work best in stable, daily routines. Medication management systems such as CollaboRhythm [15] and

Colorado Care Tablet [16] have applied clock metaphors in their user interfaces to provide a known concept into the design. However, the clock metaphor may be challenged due to complex medication needs [10].

1) *Reminders*: Systems to support medication intake usually involve different forms of reminders. Designing medication reminders is complicated due to the heterogeneous nature of the receiver; people with different abilities and needs in medication management [17]. Reminders exist in both simple and more elaborated forms. Simple reminders include SMS texts/warnings, voice messages and mobile web applications [18]. SMS based systems usually apply a 'fire and forget'-strategy; the reminder has been sent but do not require a feedback of the user's action after being received. More elaborated reminders range from smartphone apps to activity recognition systems. For instance, the app UbiMeds allows integration of a Personal Health Profile to upload a person's prescribed medication [1] while PillboxApp provides medication list management and overviews [19]. In Pillboxie the user can setup and receive medication reminders [20]. In the app MedBox users can download images of, or take photos of their own, medication [21]. And, activity recognition systems explore how activity and proximity can be used to remind a user [22]. These activities can be 'sleeping' or 'waking up' and proximity refers to where the user is when being reminded.

2) *Augmented medication pillboxes*: A number of augmented pillboxes exist such as MedTracker [23] and the smart pillbox [13]. A pillbox is not always a sufficient solution, and other tools such as calendars come in play when trying to understand medication challenges [13]. SmartDrawer is an example of a combined 'medication drawer and reminder'-system based on RFID technology [24], and specific Caregiver modules have been developed to allow caregivers to monitor the medication intake among for example older adults [25]. GlowCaps [26] is a cap that fits on normal prescription bottles and handles automated reminding and records date and time when it is opened. MoviPill [27] creates a persuasive game for older adults to address adherence issues.

C. Design Considerations for Medication Management

Existing design guidelines to support medication management include: 1) principles for home-based medication management [14], 2) guidelines for the design of Personal Health Application [16], 3) implications for medication reminders [28], and 4) recommendations to support self-reflection [13]. We acknowledge and complement the previous set of design considerations through the medication specific particularities that we identified in our work.

D. Patient-Healthcare System Collaboration

A range of remote monitoring projects supporting the communication between patients at home and the hospital has been developed [29, 30]. Others have focused on collaboration between actors (both professional and amateur) in care networks to provide best possible care across organizational

and social settings [31]. Collaboration often takes place among actors that share a common goal and values. Different rhythms and goals among the collaborative partners can be challenging. Indeed, persuasion, trickery and even force are all part of working out a collaboration and this process is shaped by for example existing power structures [32]. To be aware of, and design for organizational and individual differences while supporting collaboration seems important. Negotiating medication intake in terms of concordance [4] may be one fruitful strategy.

However, different levels of illness and age-related symptoms challenge a successful intervention [16] and existing, technological aids might not always be sufficient to sustain a successful home-based medication regimen. Based on the related work, we investigated how to improve both medication consumers and physicians' local awareness across care settings (e.g. patient-doctor communication and cooperation) to contribute and enhance the individual ability of managing medication in non-clinical settings.

III. USER STUDIES

This project integrates qualitative studies and a quantitative survey to establish an understanding of older adults' medication management. The work extended into a user-involved design process including interviews, creative workshops with older adults, developers of the Shared Medication Record (SMR), medication consultants and pharmacists (i.e. medication experts) (see Figure 1). The SMR is a Danish, national service that allows health actors and citizens to access people's prescribed medications.

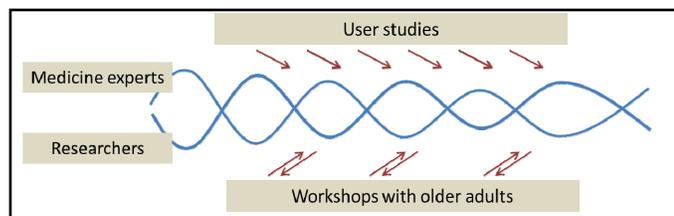


Figure 1. The project design process (time progress from left to right). The iterations between medication experts and researchers continuously integrated feedback from older adults and got informed by the user studies.

The quantitative study included 316 telephone interviews. Participants were recruited from a list of all citizens over 60 years old provided by the local governments of two Danish municipalities. They fulfilled the following requirements: 1) they manage their own medication, 2) they have been prescribed medications for at least the last three months and 3) they take either more than one medication dosage (amount) or more than once a day (frequency). The project partners defined the questionnaire and contracted a market research institute to perform the study. Questions touched upon the participants' amount and frequency of medication intake, their compliance and noncompliance, their mnemonic (assisting memory) rules in medication management, their medication information needs and use of technology.

The qualitative user study has been conducted to qualify, confirm, and further investigate aspects of the quantitative study. This study touched upon the same questions as the

quantitative study and included nine older adults. They all fulfilled the same requirements as those of the quantitative study. The participants were between 60 and 93 years old (two males and seven females), and their daily medication intake varied from 1 to 32 doses including pills, creams, eye drops and injections. Four participants managed their own medication, while five received assistance from a nurse every second week. Two of them were additionally assisted by their spouses. One participant who received assistance expressed a sincere will to return to an independent medication management.

As part of the participatory and user centered design process, we carried out workshops and interviews with additional seven older adults (five females and two males) and seven medication experts. The older adults were between 57 and 87 years old and their daily medication intake varied from 1 to 35 doses. During workshop activities, these participants were asked to write down their daily routines, including their medication intake on a paper-based calendar. Interview questions touched upon the same questions of the previous studies and approach to technology at home. The medication experts were two healthcare workers, two doctors, a developer from SMR and two pharmacists.

IV. EVERYDAY MEDICATION MANAGEMENT

The results of the user studies show several similarities between the participants in the qualitative and quantitative studies. In all, our user data confirms that the participants are often challenged in their day-to-day medication management. We now present the most relevant themes from our diverse user studies. The themes emerged as being the most frequently discussed and emphasized topics by the project participants.

A. Medication Intake at Home

The diversity in applied strategies to manage medication among these participants illustrates a continuum where older adults in periods can get help from different care network actors. Such assistance can change over time, both increasing and decreasing the amount of help received from both professional (e.g. a homecare worker) and amateur (e.g. a family member) members of a care network (see Figure 2).

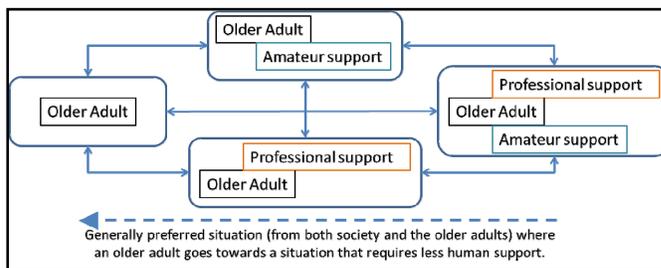


Figure 2. Older adults moving between an independent care situation (left), receiving medication assistance from one (middle) or more (right) care actors.

When an older adult returns from a hospitalization s/he might be assisted in managing (parts of) the medication for a period, and later, as the situation stabilizes, returns to a self-managed situation. Or s/he might get more help over time, due to more complicated medication regimen. Such support may be

initially provided by a spouse and later a professional homecare worker. Moving along the continuum (the arrows in Figure 2), towards a more individualized medication management, can e.g. 1) take place as a medical condition is improving or stabilized or 2) facilitated by a (technological) intervention or 3) a combination of the previous two.

1) *Intentional non-adherence*: Intentional non-adherence occurs when people intentionally decide not to follow a medication regimen. The quantitative study shows that 23% of the participants intentionally do not follow the prescribed regimen for different reasons. Some quit their medication intake if they believe it does not work or due to (fear of, or experienced) side effects or mistrust in the medication. This group has a greater need for information than the rest of the participants. Others skip their medication because of irregularities in their everyday lives. One participant said: *"If I've eaten late, I'm skipping my evening medication because I don't want to stay up two hours more just to take my medication"*. Others are intentionally not following the treatment if they feel that their disease is under control.

2) *Unintentional non-adherence*: Unintentional non-adherence occurs when people do not follow the medication regimen without an explicit will to do so. The quantitative study shows that 34% of the participants do not adhere to the medication regimen because of forgetfulness, misunderstanding of instructions, they are busy or not being at home. A participant said: *"I have my doctor's medication in the bathroom. Because to begin with I forgot those blood pressure [medications].... that wasn't so good. I did that often"*. Furthermore, our study shows that unintentional non-adherence does not increase with the number of pill quantity, but with the frequency a person takes the medication. Unintentional non-adherence is not necessarily because of forgetfulness but can be the result of a human error. A participant described one such event as she took her medication while visiting a church. Due to the bad illumination she took the wrong pill from her medication 'travel-pack'. While she tried to adhere, she made a mistake due to the pills' similar appearance and the surroundings' bad illumination.

3) *Breakdown of routines*: The qualitative study confirms that medication has a great impact on the participants' everyday lives. Most of their daily activities are adapted to the medication intake, just as the medication intake is regulated according to different activities. One participant says: *"When I'm not home in the evening I take my medication when I return. I never bring my medication out of the house"*. This is confirmed in the quantitative study where 56% of the participants rarely bring medication outside their homes, and 30% have privacy concerns taking medication in public. However, 24% of the participants take medication outside their home several times a month. When participants are not at home and routines are broken, the risk of forgetting a medication dosage increases.

4) *Mnemonic rules*: It is natural that people create different routines to remember their medication. An older woman says: *"I have the little dispenser lying on the table. So I cannot avoid seeing it"*. Indeed, 79% of the participants in the quantitative study do something special to remember their medication such as taking the medication with meals (26%) or having the medication visible (22%). In addition, 36% have bought a pill-dispensing box. Most participants distinguish between real (prescribed) and 'unreal' medication ('over the counter'-medication and vitamins) as they place them in different locations. However, the routines seldom include the less frequent actions related to everyday medication management such as the refill activity. For example, participants are challenged when it is time for medication refills, a participant told us that *"It's always hard to get hold of the doctor, and it's always in the morning that I miss it [forget to refill medication] and then it takes 20 phone calls before I get through..."*.

5) *Information about the medication*: The qualitative study participants are challenged when the medication's name changes, for example when a pharmacist substitutes one medication with another. The participants also find it challenging when provided different information from for example a nurse and a doctor. A participant said: *"The nurse told me that I don't have to take them all... but my doctor said you have to... and then who do you listen to... I have to listen to my doctor right?"* 75% of the participants in the quantitative study have a high need of medication information and 58% were proactively seeking medication information. The main sources of information were: the Internet 41%, the patient medication information leaflet 36% and the pharmacy 10%. Two participants from the qualitative study emphasized the importance of calling their physician to get medication information.

6) *Supporting a heterogeneous care network*: As discussed, and visualized in Figure 2 above, medication management is not only a private affair. Nurses, spouses and other family members can at time have an active role in older adult's medication intake. This form of support was directly observed in the qualitative study. For instance, a spouse said: *"...I have figured out, that I should make him eat them [the medication] together with the dinner. It can't be later as then he goes to bed..."*. However, this support is not always stable over time and the participants preferred as much independence process as possible in their own medication management.

B. Medication-Specific Requirements in Practice

As illustrated in the 'Related work' section, numerous studies have examined adherence in non-supervised settings such as private homes. However, to support medication intake in non-supervised settings one has to consider a range of exceptions and special situations, which can be hard to depict for a design team. For example, during the user involvement (see Figure 1), specific medication particularities emerged that can challenge medication consumers in everyday life. As a result, the project's medication experts became aware of, and

could further unfold such situations and how the following particularities can challenge an individual medication regimen.

1) *Substitute medication*: As illustrated above, participants were challenged when the medication's name changed. Similarly, medication experts expressed that many different medications exist with the same effect but under different names and manufacturers. In Denmark, it is the pharmacy that offers these substitute medication. The pharmacist might do this to lower the medication's cost. While this indeed can help the wallet of any medication consumer, it can also add complexity in the medication management. For some medication, the prices changes often, leading to regularly changes in medication brand and naming. This is confirmed in the qualitative interview where a participant told us: "*I don't know the name because it's something new every time you buy - it is a different drug. It's called something different every time (...). So I took the wrong pills, I couldn't figure it out*".

2) *'According to need' – medication*: Not all medication is taken regularly, or it is up to the individual to decide when to take it. The medication experts confirmed this. Indeed, "According to Need"-medication is not suited for reminders. It can be a medication that is prescribed by the doctor, for example a cream, but that the patient should apply only when needed and not on a day-to-day basis. For example, a participant had, at times, been prescribed up to 12 different types of so-called 'according to need'-medications that she could take if necessary. Also, she was only allowed to take a specific amount each day, which complicated her medication management. The experts emphasized the importance of documenting "According to Need"-medication intake, to get a more complete overview of an individual's medication intake.

3) *Delayed medication intake*: Analyzing the user-study material, the medication experts emphasized the need to take medication within a certain time interval. A participant noted the importance of taking her painkillers at a specific time, because when she forgets, her pain increases and the pills will no longer be as helpful. However, some medication can be taken later than prescribed. A participant was informed that it was possible to delay the intake of so-called "water pills", that increases the production of urine (diuretics). So, the participant started to adjust the water pill intake, making sure there was a bathroom nearby after the medication intake. Also, a morning medication may be taken at lunchtime or at the evening and medications that are taken more sporadically can, occasionally, be taken within a week's time. Other medication should be skipped if a dosage is missed. Indeed, the recommendations for delayed medication intake, varies with each medication and depends on what other medications are taken.

4) *Overview and knowledge about medication*: The medication experts emphasized the importance of providing an overview and knowledge about medication at home. This becomes more critical if there is more than one individual following a medication regimen at home, and even more critical if they are prescribed the same medication. The experts

stated that it is necessary to provide an individual medication overview for each person in the household. Taking a medication can be so integrated into older adult's routines that a registration of whether or not they have taken a specific dosage is needed. For instance 12% of the participants had problems remembering whether they have taken the medication. Indeed, a dosage of medication can be prescribed for several times during a day and the registration on daily basis can facilitate an overview of medication intake for both people and practitioners over time. For example, a participant was prescribed 32 medications during a day and at different times (7/11am and 12/16/18/22pm). She found it difficult to take the medication (at the right time) and get a comprehensive overview of her medication intake. As illustrated above, a medication consumer occasionally receives different messages from different healthcare professionals regarding when, how and why to take a specific medication. This also challenges the understanding of the medication, the prescribed regimen and reduces medication adherence.

People are also prescribed preventive medication. This medication aims to decrease the risk of future health condition, for example stroke. Medication experts stressed that people should be informed about the effects and reasons of preventive medication as they also increase the complexity of the medication regimen. A medication expert said, "*It [preventive medication] is great if you are young but not when you are 85 years old*". Moreover, the experts stated that *fine-grained* information such as "*do not crunch the pill*" or "*shake the bottle before use*" or "*to wear gloves when taken the cream*" is extremely important and should be accessible to people. It is very important that a person has access to the correct and necessary medication information, such as administration instructions and food interactions. A participant explained that there are types of food that she should not eat together with her medication but she doesn't really know which.

5) *Doctor's insights in everyday medication management*: The medication experts emphasized the importance of the doctor-patient relationship and the doctor's insight in patients' everyday medication management. This insight is considered valuable both in situations of adherence and non-adherence. Today, the doctor usually lacks this insight in different ways; first, when patients are unintentionally non-adherent without later becoming aware of this, they naturally cannot tell their doctor. For example they might have misunderstood a prescription, and hence take just one out of two prescribed doses a day. Second, if the patient intentionally skips the medication, both doctor and patient would benefit from sharing this information. The patient might have planned to consult the doctor on this matter, but might forget this during the consultation. Indeed, many participants in our study bring notes to remember what to talk about with their doctor. Third, a patient follows a regimen, but wishes to consult the doctor about experienced side effects or challenges with integrating the prescribed medication into his/her daily routines. For example, a participant was prescribed a cholesterol pill at night

but she was taking it during the evening with dinner because she worked at night. A medication expert commented on this, stating, “those [cholesterol] pills are not allowed to be taken together with food”.

V. DESIGNING ACROSS CARE SETTINGS

The findings show the importance of both medication consumers and experts’ involvement to reveal new challenges in supporting medication management practices. In this section, we discuss challenges, opportunities, and a set of design principles for pervasive healthcare medication management system (PHMMS). These design principles complement the pre-existing guidelines (See Related work) to account for individual and medication particularities to better support older adults’ medication intake across care settings.

A. Individual Medication Overview

The number of pills, different types of pharmaceutical formulation and frequency of dosage describe the complexity of medication regimens. Indeed, medication comes in different shapes and forms. Some have special markings while others are more anonymous in their appearance. Also, there could be a potential mismatch between the prescribed medication and the medication handed out to the person at the pharmacy – so called substitute medication. Moreover, some “according to need”- medications have restrictions on how many doses can be taken within a specific time frame. Therefore, documenting “according to need” intake could support a person in keeping track of this medication and could help to identify a change in the medical condition. These in-home and medication particularities can enhance the individual medication overview and improve the physician’s local awareness [7] regarding the prescribed care plan at home.

Our findings suggest *the design of PHMMS that enhances the individual medication overview by visualizing, documenting and supporting the use of substitute and ‘according to need’ medication*. This implies an automated update about what medication the doctor has prescribed and what the pharmacist actually has handed out. For example, a person might still have some medications left, when buying the new substitute medication and hence both the prescribed and handed out substitution medication must be made visible to people at home. The use of ‘according to need’ medication should also be reported and attached to the individual medication overview. This is something not found or outspoken as a concern in the related work of this paper. This complements [14], that calls for a distinction between real and other medication (i.e. supplements). Indeed, substitute or ‘according to need’ medications are real medications and should be accounted for medication management technologies.

B. Shared Responsibility

Doctors are in charge of defining a specific *care plan* based on their expertise and the patients’ treatment goals. However, the care plan is sometimes given to patients without discussing its consequences or without the physician knowing

what is happening in the patient’s everyday life. This can result in only a minor improvement or even a negative health trend. The medication experts emphasized that doctors should inform, and discuss with, their patients about the reasons and consequences of each prescribed medication, including preventive medication. Limiting the number of preventive medication can be favorable, especially for older adults with a complex medication regimen. Here concordance [4] can evoke a shared responsibility that fosters an active participation from both settings. Aligned with [13], collaboration and sharing of behavioral data among the care network members are needed. Health care providers should promote, motivate, encourage and follow up on people according to mutual goals. Still, people should take responsibility to perform self-care activities and to report back to their health providers. In a clinical setting, physicians have improved their *local awareness* about the health status of their patients using cognitive artifacts [7]. However, when a patient is at home, the lack of knowledge between consultations about what happens in the home hinder a complete overview of the medication intake. For instance, sharing issues about general problems and unintentional non-adherence can enable a patient-doctor dialogue about this issue and hence both the doctor and the patient should be aware of the patient’s challenges in following the prescribed medication regimen. Sharing issues about intentional non-adherence can enable the patient to document why a medication has not been taken as prescribed, for example due to the fear of side effects. Therefore, a care plan can be improved by gathering people’s expertise regarding the home context, obstacles, facilitators, implications, feelings and in general details of individual’s behavior [13]. Thus, the local awareness in non-clinical settings can be seen as all factors that affect a medication intake activity and that can be used to expand physician’s local awareness to promote and improve care outcomes.

Our findings suggest *the design of PHMMS that supports the shared responsibility by providing the individual’s local awareness and enhancing the physician’s local awareness of medication intake taking advantage of the individual medication overview*. In this sense, the individual medication overview turns into a cognitive artifact [7] that can facilitate the shared patient-doctor responsibilities across care settings.

C. Beyond Capturing, Reminding and Monitoring Medication Intake at Home

Clearly indicated in our study, there is a need for updated, validated and especially relevant medication information from trustable sources. People are actively searching for medication information from different sources (e.g. Internet, patient medication information leaflet, pharmacy). However, the participants did not want a complete “*Patient medication information leaflet*”. Consistent with [28], our results show that pervasive healthcare medication management technology should support active information search from trustable information sources. Preferably, but still technologically out of reach, the information should always be tailored showing only what is relevant for each individual at any given time and

situation. Fine-grained details are necessary to support self-medication as stated by medication experts. This has strong implications for the design of pervasive healthcare medication management technology. The integration of these different sources can facilitate a sense making and self-reflection process. Hence, supporting an active search go far beyond the passive capturing, monitoring and reminding functionalities in much existing medication management technology. People should know what to do, if for example a medication is forgotten, to maintain the right medication informational order. The medication informational order refers to the all aspects (e.g. who are the sender and receiver, how the trustable medication information is delivered, what type of medication information is interchanged – instructions, side effects, food interactions) of the information flow between care settings [32], that should be available at hand to support the medication activity.

Our findings suggest *the design of PHMMS that sustains the medication informational order to enhance individual's sense making and reflection*. The informational order complements the gathered knowledge (e.g. people's routines, available spaces, individual's behavior) from the home [13]. A proper combination of the medication informational order and gathered knowledge from the home can enhance the individual medication overview and provide a sense of local awareness. The individual local awareness can be enhanced by applying information visualization techniques as proposed by [13]. In doing this, individuals get the ability to explore, compare and analyze their own medication intake through the individual medication overview. This principle also complements [16] that focuses on interface messages in medication management systems. The right phrasing, visual representation, terminology, individual's behavior and the medication informational order can assist a more complete sense-making and reflection process to facilitate the individual's understanding of the current care plan.

D. From Medication Adherence to Integrated Adherence

The home is not designed as a place for care and people might live out different roles, and activities, at home compared when they are in a clinical settings [33]. Thus, it is important to support people to insert the medication activity into their daily routines and their available space at home. There are a high number of participants who attach their medications to their habits and routines and, indeed, it seems that medication management is more complex when older adults have an active lifestyle as 1) people are not always at home or in the vicinity of their medications when it is time to take their medication and 2) some people feel uncomfortable bringing medication outside their homes. Furthermore, the mnemonic rules show that when routines are broken, remembering a medication dose is a common problem. In addition, forgetting to request new medications, as they are about to run out increases the risk of non-adherence. Consequently, people do not know what to do if a medication is forgotten - should for example the missed dosage be skipped or a double dosage consumed the next schedule time, and will it be possible to

delay a specific medication intake. Besides the necessity of customizable reminders [28], an integration of the daily medication regimen with a person's daily activities can promote adherence when daily routines are broken. This integration can facilitate the reminding process, as people should receive reminders when it makes sense according to their needs to prevent unintentional non-adherence.

Our findings suggest *the design of PHMMS that supports the adjustment of medication intake according to prescription times, people's routines and the respective time interval in and outside the home*. This principle calls for an attention to the specific reminder time interval in which a certain medication can be taken. Recognizing, and designing for, this medication-intake interval would allow an individualized adjustment of people's medication intake. This adjustment accounts for planning, reminding and supporting the intake, identifying activity-medication conflicts to hence adjust the intake (according to pre-established rules) to suit people's lives. This complements customizable reminders guidelines provided by [28]. As explained above, this goes beyond simple reminders, as the medication informational order should also be available at hand. Furthermore, technology should help remind people to order/re-order new medication as it is about to finish and whether or not a delayed medication intake is possible.

E. The Heterogeneous Care Network

Both the older participants and the medication experts have discussed the importance of 1) motivation and 2) to be continuously encouraged to follow a medication regimen. As illustrated in Figure 2, the older adults in our studies received both amateur and professional medication support. From this perspective, the network of actors surrounding an older adult with a complex medication regimen plays an important role in supporting adherence and motivation. But, supporting the coordination of cooperative care work at home is not an easy task as relatives and clinicians have their own values, rhythms and attitudes [34]. For example have [13] suggested the use of data annotation to support collaborative task sharing to avoid misinterpretations. Medication management technology should sustain both amateur and professional care providers to play an active role in the older adult's medication intake and provide them with a sense of local awareness.

Our findings suggest *the design of PHMMS that sustain and allow (both amateur and professional) caregivers to play an active role in the people's medication intake by providing caregiver's local awareness taking advantage of the individual medication overview*. The overview is important to provide caregivers with local awareness as people move away from an independent care situation (see Figure 2).

VI. CONCLUSION

This paper shows the importance of looking beyond single strategies and solutions (e.g. medication reminders or pillboxes – technological augmented or not) targeting a specific subset of users or illnesses. Rather, there is a need to develop a more complete understanding of what it means to

live with an illness and to be in need of medication management support in everyday life. This paper discusses six important particularities of everyday medication management (*according to need medication, the heterogeneous care network, the substitute medication, the medication informational order, the shared responsibility and the adjustment of medication intake*) that have not, to our knowledge, been adequately discussed within the Pervasive Healthcare community. Our findings suggest that generating a more complete and individual medication overview, that accounts for the individual's and medication particularities discussed in this paper, can: 1) provide both care receivers and (amateur and professional) care givers with an understanding and local awareness of the medication intake; and 2) expand the physician's local awareness of the current care plan.

Our findings come from a project working with older adults, but they may be transferrable to other age groups as well. From the aforementioned particularities, we introduce five design principles (see Section 5: *Designing across care settings*) to support designers in developing future pervasive healthcare medication management systems.

To deal with some issues presented in this paper, might require a national investment (e.g. infrastructure for medication information or technological frameworks) to integrate solutions and systems from different levels of the healthcare system. However, while such a development might be out of reach for most designers and developers, it is important to be aware of the herein presented issues and their impact on pervasive healthcare designs. Furthermore, the presented findings are most likely far from complete, and we encourage the Pervasive Healthcare community to continue discovering and understanding particularities of peoples' everyday medication management. To preserve an independent care situation as long as possible, we suggest moving away from solutions focusing on one specific strategy such as reminders, towards solutions that consider the wider spectra of issues existing in everyday medication management.

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