

# Of Pill Boxes and Piano Benches: "Home-made" Methods for Managing Medication

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## ABSTRACT

We report on the results of an ethnographic study of how elders manage their medication with the objective of informing the design of in-home assistive health technology to support “medication adherence.” We describe the methods by which elders organize and remember to take their medication—methods that leverage a kind of distributed cognition. Elders devise medication management systems that rely on the spatial features of their homes, the temporal rhythms of their days, as well as the routines that occasion these places and times to help recall and prospective remembering. We show how mobile health care workers participate in the development and execution of these systems, and “read” them to infer an elder’s state of health and ability to manage medication. From this analysis, we present five principles for the design of assistive technology that support the enhanced but on-going use of personalized medication management systems, and that also allow for remote health care assistance as it becomes needed.

## Categories and Subject Descriptors

J.3 Life and Medical Sciences—Health, Medical Information Systems, H.5.2 User Interfaces—User-centered design, H.1.2 User/Machine Systems—Human Factors.

## General Terms

Design, Human Factors.

## Keywords

Assisted living, health care, elder care, medication, drugs, pharmaceuticals, adherence, compliance, distributed cognition, external cognition, intelligent environments.

## 1 MEDICATION MANAGEMENT IN ASSISTED LIVING

In-home health care has received research and development attention because it is believed that thoughtful innovation can extend the length of time that people stay in their homes. As the world’s old-age population continues to rise, the hope is that such technological advancements can defray expensive health care costs while maintaining the dignity of citizens who can continue to manage their own care in their own homes and communities.

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We report on a study of in-home health care for elders, with a particular focus on how elders and their health care providers manage medication. Taking medication at the right time and in the right amounts is an important aspect of in-home health assistance, though it is a difficult one to support. Remembering to take medication—and remembering if medication was already taken—is a challenge for many of us no matter our age, but is a particular problem for elders with compromised health [8, 10, 21]. Elders often have many medications to manage throughout their days, and forgetfulness can be an additional challenge for this population. Some health conditions are such that people who forget to take their medication will deteriorate physically and mentally, making it even more difficult to remember to take future doses. Yet, monitoring consumption is very difficult. Short of invasive measures—sampling blood or urine for example—or eye-witness confirmation, it is difficult to be assured that a person has taken the appropriate dose.

## 1.1 Elder versus Clinical Perspective

Our research was prompted by a third-party development and pilot deployment of a new information system intended to track elders’ drug consumption and transmit this information and other health measures to remotely located health care workers. In this technology case, the system was primarily designed for the benefit of the health care workers, and therefore resulted in a design that favored clinical depictions of drug use. As such, this system relied on the ability of elders to know their medication names and dosage, as well as adhere to exact times of consumption. This problematically divorced elders’ understanding of their medication from situated activity to one of post-hoc knowledge and recall [4], and resulted in a system that queried users to, for example, “Confirm that 5 mg of Novrad was taken at 0730.”

Our research has instead found that daily medical management by elders in their homes leverages a kind of *socially distributed cognition* [18] that makes use of features of homes and schedules as well as other people to help with planning, organization and prospective remembering, the need to “remember to remember” [28]. Our investigation shows that people manage their medications—with only partial information about what the medication is—through a set of personalized spatio-temporal arrangements and routines that they devise in their homes. These physical arrangements and routines provide a sense, structure and rhythm to intake even when people know very little about the medication itself. In contrast to our example above, this translates into useful and reliable knowledge about medication that is encoded into external representations—physical features of the pills, their containers and the home environment, as well as temporal features of a person’s

day. An elder’s practical knowledge that medication was taken, then, looks more like this: “The pill I already took today was in the first bottle in the row of bottles in my kitchen cabinet, taken immediately after my breakfast.”

While these kinds of confirmation reports might not appear to be especially precise because they are not framed in a clinical fashion, we believe that these realistic accounts of intake can also be reliable. Our goal is to show how personalized medication management systems are intelligent even though they do not always conform to clinical standards of medical description, and that those existing systems can be leveraged with IT support to enable ongoing independence with computer-mediated remote assistance.

We also found that those same handcrafted routines and arrangements that exploit features of one’s home environment also serve as resources for mobile health care workers. Health care workers are able to “read” and support the creation of these personalized systems to communicate with their clients and to assess needed levels of care. They *infer* that all is in order by talking with the elder, checking the current state of the medication (its orderliness, remaining amounts and so on), and assessing the physical state of the home.

What is important when considering the future of IT in the home for assisted health is to appreciate that IT needs to support these grounded, folksy descriptions—because that is the manner in which people think, act, and feel intelligent and autonomous. By extending existing methods for medication management through integrated IT support, the methods can be adapted to people’s changing health and assistance needs over time.

## 1.2 Adherence Through Support

In this paper, we have largely chosen to use the phrase “medication management” as opposed to “medication adherence,” “patient compliance” and “drug administration.” These latter terms are what the clinical literatures tend to use; “adherence” and “compliance” speak to a clinician’s perspective of keeping to intake schedules, and the term “drugs” emphasizes prescription medication. We have elected to refer to and study “medication management” for two reasons: we want to more closely identify with the elders themselves, who are more likely to refer to drugs as “medicine” and “medication.” It also allows for conceptual inclusion of non-prescription drugs, including vitamins, supplements and over-the-counter medications.

However, “medication adherence” and “patient compliance” to a drug regime of course are serious concerns. Some of the most recent research in the gerontology literature [10] shows that “compliance” is at about 75% on average, meaning that, across the sample population, only three-quarters of medications are taken by elders managing their own medication. Our take on this problem is to consider how elders manage their medication with the assistance of health care workers, so that we might be able to implement IT to 1) better support the creation of and interaction with those personalized systems in order to 2) further improve dosing reliability and 3) more accurately measure and monitor medication “adherence” by 4) modelling remote, computationally-supported assistance for medication management on face-to-face assistance.

We report on the findings from our qualitative investigation of eldercare in the Danish social welfare system. We studied 10 elders who are living in their own assisted-living apartments and are visited sometimes multiple times a day by mobile health care

workers. From this, we derive principles for design for IT for in-home health care, particularly with respect to medication management.

## 2 DESIGNING FOR THE HOME

There is a large body of work in the arena of assisted living. For example, research projects stemming from Georgia Tech’s Aware Home initiative, including the reverse family portrait [24] and the cooking assistant [6], are based on making it possible for people to age “in place” by emphasizing familial social connection and providing assistance in critical everyday tasks, respectively. The multiple-partner interLiving project [19] addresses matters of intergenerational family communication. Assistive technologies for people with disabilities also are designed with the intention of enabling people to help themselves with remotely located practical and emotional support [5]. The “care in the community project” has developed a wellness index and overview, which provides caregivers with views of how elders are doing by considering what activities are truly measurable and indicative of well-being [3]. The ELDeR project has considered how elders are supported by an ecology of people, products and activities in the physical context of home and the emotional context of community [14, 17]; this perspective has helped inform ours here. These are just a few examples of the growing body of work in assisted living.

On the medication front, the gerontology literature has researched “medication adherence” and “patient compliance” to medication regimes extensively, though these investigations tend to examine quantitative aspects of management—how much medication is consumed by considering different populations, health, age, and dosing variables [8, 10, 21]. In the human computer interaction literature, there is some systems-oriented work in this area, including exploratory work at Georgia Tech using the Memory Mirror system [26]; The EQUATOR project’s MediPic prototype [7]; and Wan’s Online Medicine Cabinet [27]. Fishkin, Wang and Borriello [13] developed a system for medication monitoring that supports some of the real practices we observed by relying on smart surfaces that build on people’s own methods for medication management. In particular they support the idea of the distribution of medication across spaces in the home. We hope our investigation of elder-centered practices complements and extends this work, as well as these other HCI-centered approaches for supporting medication management.

Our work is also guided by research that pertains to more general issues of designing for the home and households. Most notably, we draw on the findings and insights of Taylor and Swan [25], Crabtree and Rodden [9] and Edwards and Grinter [12]. No matter the target user audience (elders, parents, children, people who need additional assistance and so on), homes are special environments. As Edwards and Grinter [12] point out, people at home have different technological needs and expectations than at work, and designing for these environments is qualitatively different. The home is its own institution that operates under rules and expectations for privacy, communication, conflict and so on that might be different than workplace environments. Homes are places where any number of activities take place by different actors throughout the day, from meal preparation, to laundry, to entertainment, childcare, emotional connection and so on. Technology there is often introduced piecemeal and so needs to be compatible with devices introduced before and later. Domestic technology needs to be especially robust and reliable and allow

people to continue their activities even in the event of technology failure.

Crabtree and Rodden [9] and Taylor and Swan [25] closely examine information-based activities of the home—processing postal mail and keeping track of family members’ schedules, respectively—illustrating that households use features of spaces and places within homes to develop means for coordinating plans, sharing information and essentially doing the work of home. For example, mail comes into a home and is moved to different locations depending on its status, intended audience, and the set of actions it might invoke (bill paying later in the month, making a phone call for followup, writing a thank-you note). Resting in a pile next to the front door, it signals one thing (unprocessed); opened at the center of the kitchen table before a meal it means another (something for the family to share perhaps); sitting unopened in front of someone’s bedroom door, it means something yet again (intended only for that person). Crabtree and Rodden [9] explain that it is the routines of the family and their commonly-understood organization of the mail that create the sense and purpose for members of the household.

Taylor and Swan’s work [25] on the management of things like appointments, reminders and so on in a family home extends these insights to show that with these locations of information and activity, families develop and rely on artful organizing systems that are distributed across places and artifacts within the home. The home itself offers places that generate additional meaning depending on the arrangement of materials and information there. As we hope to show, our investigation of medication management echoes some of these findings, though the extent and purpose of spatial distribution can be different, as well as the nature of collaboration in the medication case. Temporal patterning plays a central role in the management of medications as well.

### 3 THE ELDERTECH STUDY

#### 3.1 Elder Care in the Danish Welfare System

Denmark is a social welfare state. Health care is available to everyone, and includes assistance in older age that strives to keep citizens for as long as possible in their own homes or “protected residences”—homes that are located close to health care professionals for more immediate care if needed. This philosophy is in keeping with Danish ideals of enabling people to help themselves in most everything they undertake no matter stage of life, and happens to accord with a growing world-wide need to find ways to care for a progressively aging population “in place.”

The Danish welfare system provides a variety of services to elders that can include nursing care as well as home-help assistance like house cleaning and personal hygiene. Needs are assessed by the local municipality. Nursing care is always provided free by the municipality. Home-help and other personal services might incur a fee if the health condition is a temporary one, but not if the health condition is permanent. Elders are entitled to the same care services whether they are in their own homes or have moved into protected residences. Protected residences can be long-term homes for elders; they are not simply short-term stopping grounds before more intensive care becomes necessary [1].

Assistance for elders is organized by what is called the Local Center in their geographical area. Several professionals are employed by each Local Center: Nurses, Assistants and Helpers, physical therapists and occupational therapists. We focused on the work of

the first three professions, as they have regular schedules for visiting citizens. Nurses have the most medical training, and coordinate long-term medication plans with doctors, make medical assessments, and so on. With citizen-specific training by Nurses, Assistants can provide some medical support like changing wound bandages, giving injections, changing leg support stockings, etc. Assistants visit more frequently than Nurses to provide regular care and assistance, and, in comparison to the Helpers, handle the more complex, medically-involved care cases. Helpers do little medical work, but both Assistants and Helpers assist with personal care like bathing, dressing, making beds, housecleaning, and meal preparation. In this paper, we will use these titles when we are referring to the particular professionals, but when referring to them generally, we use “health care workers” who provide health care “assistance.”



**Figure 1:**  
The nurses’ office in the Local Center is located behind the protected residences

For our study, the Local Center has purview of 114 protected residences but also provides less frequent help to 600 other citizens living in regular residences in an even larger geographical area. The protected residences, where our participants live, are buildings that belong to the municipality and are situated closely to the Local Center (see Figure 1). They are apartments between 65 and 80 m<sup>2</sup> (or 700 to 860 ft<sup>2</sup>) modified to meet the needs of elderly people but are otherwise comparable to city center apartments. Hence, there are string-pull alarms in each room that the elder can trigger if help is needed, which are in turn answered by Local Center staff. Each has a living room, kitchen, a large bedroom and spacious bathroom. The size of the rooms accommodate special furniture and aids such as hospital beds and walkers, and for the staff to work more easily within the space of the apartment. Elders furnish the apartment with their own furniture and decor.

#### 3.2 Participants

We worked with a nearby Local Center to find 10 elders who received at least one health care worker visit a day and were able to participate for an extended period of time. We studied health care workers out of the same Local Center. All participant names used here are pseudonyms.

##### 3.2.1 Elders

The participants were seven women and three men between the ages of 65 and 88 years with an average age of 81 years. They all lived in protected residences, and at the time of the study, eight of them lived alone and two lived with their spouses. The length of

time in their apartments ranged from one month to eight years. Four citizens made use of wheelchairs (though not necessarily inside their homes) and four used walkers. All had compromised physical health that required medical assistance but various degrees of personal care assistance. Over the entire project period of 9 months, each of the elderly participants was hospitalized for some period of time; two passed away late in the project period.

### 3.2.2 Health Care Workers

Six health care workers served as participants in our data collection, and included two Nurses, two Assistants and two Helpers. They have many years of specialized experience in eldercare, ranging from 11 to 25 years.

## 3.3 Method

We conducted field studies at the Local Centre over a period of 9 months. During the last 4 months, some of our elders had a computer system installed in their homes that was intended to record reported drug intake as well as capture different health measures. Over the whole of the project, we used ethnographic methods to study what was initially a fairly broad set of interests in the domain of elder care, with an eye to understanding how elders manage their own health, the function of the health care worker visits, means of social connection, the function of the Local Center in community-building, and the nature of work of mobile health care workers. In addition to these set of concerns, the work included an evaluation of the computer system pilot. A central issue throughout the project has been the management of medication by the elders and the health care workers—the subject of our work reported here. As the field studies evolved, we tailored our methods to capture particular activities.

Initial observations were conducted at various events at the Local Center to understand the kind of activity that happens there, and to meet citizens. This included partaking in lunch in the dining hall; attending entertainment events, fitness class sessions and an internet café class; and meeting with the weekly coffee group.

Additionally, we shadowed a Nurse, an Assistant and two Helpers—all in-home health care workers—each throughout an entire workday, which has anywhere from 6 – 11 home visits. For each day of shadowing, we began by attending the morning coordination meeting where all the Local Center’s health care workers meet at the start of their shifts. Shadowing revealed how workers coordinated with each other and individually organized their appointments, paperwork and equipment throughout the day, observations that were also informed by Nilsson and Hertzum’s account of the coordination work of Danish mobile health care workers [22]. We focused particularly on how care is provided within citizens’ homes. We examined how health care workers oriented themselves in homes and how they and citizens interact. This observation was later supplemented by interviews with the six selected health care workers.

All ten citizens were interviewed and observed in their homes on at least one occasion prior to the computer installation. The initial interviews were open-ended and semi-structured and lasted for one and a half hours, and sometimes longer. The citizens were asked to describe their daily and weekly routines, social networks, feelings about the kind of care they receive, as well as show how they manage their medication. Two elders were videotaped while preparing their medications for the next day. In addition we studied and photographed areas of importance where medication was kept, where contact and medical information was stored, and par-

ticular places that we came to call “altars” where collections of important daily items like the telephone, remote controls, insulin syringes, and lip balm, for example, were arranged for easy access while sitting in a favorite chair.

As part of our larger research project, we observed some of the installations of the computer system for managing medication. Analytically, this allowed us to “see” otherwise more invisible matters of spatial arrangements in the home—which came to be an important focus of our study as we will explain next—that were supported or disrupted by the installation.

## 4 MEDICATION MANAGEMENT

### 4.1 The Work of the Elders



**Figure 2:**  
**Prepackaged doses prepared by the pharmacy**

Management of medication is an important activity in the lives of the elders we studied. For some, it requires a good amount of attention to organize and consume medicine. When one has to take as many as 35 pills a day, or self-administer insulin depending on blood sugar levels, the management of medication is a foregrounded activity. For some people, management of medications can become central to one’s day, and can itself serve to organize other attributes of daily schedules. Depending on individual capability, dosing may be facilitated by nurses, pre-packaged into daily dosage packets by the pharmacy (see Figure 2), or done by the elders themselves.



**Figure 3:**  
**The official municipal pillbox system**



Pillbox kits, available through the local municipal government, are comprised of 7 horizontal boxes for each day of the week that fit inside in a folder that either the elder or the nurse fills. For Marie, depicted in Figure 3, the “medication-week” begins on Thursday (Torsdag), since the nurse visits every third Wednesday to distribute pills in her pillbox system. Marie shows how she takes a new week of boxes and puts them in the folder at the far left.

In our studies of elders in their homes, we found that management of their medications was personalized to each elder and their home, and developed over time. These methods are vital to the successful self-administration of medication because, we found, except for all but two cases, elders could not readily identify what all their medications were called, and only possessed partial information about what they were for. This information was often not important to them—what was important, for example, was that they took “the small pink tablet” at breakfast and dinner, but not at lunch. This is not at all to say that elders per se are incapable of learning or knowing what their medications are or what they are for; indeed anecdotal evidence suggests that many people—young and old alike—simply take medications with only partial information about its features, including name and purpose. A few of our elders, when asked what a medication was for, knew for example that it was “for the blood,” and even then read the label for our benefit to find that, “Oh, this is for cholesterol.” Often elders *could* know what their medications are for, but they don’t *need* to know. It could also be the case that they knew at one time, but have since forgotten or, rather, deferred or reassigned or *encoded* [20] only its most salient meaning (when to take it) into an external cognitive-computational system. People use their environments to organize things and information and to be “smart” [9, 18, 23].

We found that people exploit and rely on features of their physical environment and the temporal rhythms of their day to help them organize and remember to take their medications. They spatially organize their medications, which are occasioned during the daily routines that are themselves developed over time [9]. And, because these environments are homes that reflect individual preferences, personalities, needs, and styles of living, organization of medication is also adapted to each home’s affordances for storage and placement. Medicine cabinets run out of space, kitchen shelves might become too low or high as someone ages, and so on. Medication might be found in unexpected places that are for various personal or aesthetic reasons the appropriate places for the particular home’s resident. In our analysis, we present the means of spatial and temporal ordering in medication management, as well as other factors and features of use that figure into this task.

#### 4.1.1 Spatial & Temporal Orderings

People use the arrangements of things in space in intelligent ways [20] to support internal cognitive activity with cognitive artifacts and external representations [23]. Creating and manipulating external representations of information is a natural way of supporting and enhancing human ability, and happens in all aspects of human life (food preparation and cooking [11], bartending [2], air traffic control [16] are a few lively examples in the literature). We conduct our lives in a spatio-temporal context and with other people; we build external representations of our cognitive activity as ways to mark, measure and support estimations, calculations, memory and so on. Doing so supports not only ourselves, but very often is

for the benefit or inclusion of other people in the activity, resulting in what Hutchins calls *socially distributed cognition* [18].

Figure 4 shows Ida’s medication in her kitchen cabinet. Ida seems to have little knowledge about her medications, knowing neither the names nor the purposes of most. However, she is also one of the citizens who is fully responsible for doing her own dosing. To do this, she relies on a spatial arrangement of her medication—and the path of her morning routine to occasion the arrangement—to guide her. Just below her tea selection in her kitchen cabinet, Ida has arranged her medication in a right to left fashion exploiting the natural spatial affordance of “next” in a linear order [20]. All the medication in the cabinet is supposed to be taken each morning (and only then); her morning routine, which occasions the cabinet, reminds her to open each bottle in their linear order and sequentially take a pill from each.



**Figure 4:**  
Ida’s medicine in a kitchen cabinet, taken sequentially from right to left



**Figure 5:**  
Margrethe’s special heart medication (circled) is placed away from her daily medication on the first shelf

Figure 5 shows a similar linear ordering on the first shelf, but Margrethe also takes the additional prescription medication circled in the picture for her heart based on how she is feeling. This medication is kept separate from the other medication, though in the same cabinet, an example of how physical artifacts can be *symbolically marked* as distinct from others.

The simple placement of things in spaces that have particular meaning and purpose—*places*—also cues prospective remembering. For example, Marie keeps her medication on the kitchen table, since she has to take something at every meal. Jens keeps his midnight medication by the bed on his nightstand where he will remember to take it even though all his other medication is located in the kitchen. We will return to the idea of the exploitation of space and place in short order when we discuss how arrangements in particular places evoke and support routines.

The most straightforward example of temporal cueing for taking medication is the general practice of associating dosing with mealtimes. Sometimes this is necessary, because some medication needs to be taken with food, but it also serves as a way of helping people conveniently remember to take medication and of pacing consumption throughout the day. It is much more likely that one will remember to take a pill 3 times a day at mealtimes than 3 times evenly distributed across one’s waking hours. One participant, Anna, used to use only temporal cues to remember to take her medication. Anna takes a great deal of pride in her home and likes to keep her health matters private—as such, she used to keep her medications tucked away in her piano bench, which happened to be located near her dining table. At mealtimes, she would go to her piano bench and take out her necessary medications. However, recently her medication schedule changed to include two additional times outside meal times—2pm and 5pm. Upon that change, Anna needed to resort to spatial placement reminders, and so began to use a pillbox that she filled every morning and (quite reluctantly) placed on her living room table to remind to her to take the medication at the odd hours that linked to nothing regularly notable in her day.

The power of using external representations and cues to support medication management comes in *linking spatial and temporal orderings*. In fact it is critical, and can distinguish medication management from other kinds of socially distributed information processing in the home.

The time-tested pillbox provides additional support for recall and prospective remembering by mapping a temporal representation to a spatial one. Spatially, the kind of linear ordering that we saw in the line of bottles in the kitchen cabinet is used, but the pillbox is engineered to evoke a temporal pattern as well, with each cell corresponding to a time in the day (usually morning, noon, evening and sometimes night). The absence or presence of pills in a particular cell indicates past action (having taken the pills or having forgotten to) and intended future action (must still take evening pills). They provide traceability of action, and for that, Jens says, “The pillbox never lies.”

#### 4.1.2 Routines

As we have begun to see in the above discussion, spatial and temporal orderings are intertwined. As Crabtree and Rodden describe, routines are “sequences of action [that] articulate the spatial and temporal distribution of information around the home” [9, p. 209]. We now turn to some illustrations of this.

Ida, the citizen who knows little about her medication but manages her own dosing directly from their bottles by relying on a linear arrangement of them in her kitchen cabinet, uses her morning breakfast routine to cue her to take her medications. She doesn’t have the traceability of the empty pillbox cells to help remember whether she took her pills or not; instead she offloads it to her morning routine, trusting that if she conducted her morning routine, then she very likely took the medications as well.

Routines in medication management are, as we explained earlier, associated with other activities, including eating meals and bed-times (including naptimes). Jens, who distributes his medication across his home depending on what spaces he expects to be in at certain times, relying on what Taylor and Swan might call an *artful system* [25], tells us:

*In the evening I put out the pillbox for the morning. I put it on the kitchen table, where I start my day. Those that I take at night I keep by the bed. It’s a routine.*<sup>1</sup>



**Figure 6: Jens’s Morning Counter:**

Jens’s pillbox is at the bottom right of the picture, next to his paring knives for his morning apple (located just above the pillbox), as well as a cutting board, coffee, a coffee cup, and so on.

Jens’ *consumption* of his medication as well as his *organization* of his 9 different medications are routine. He stages his morning medication on his “morning counter” (see Figure 6)—what Crabtree and Rodden call an activity center [9]—which has all his morning routine supplies. The night before he makes a point of filling the pillbox with his morning medications and placing it on the kitchen table to take at meal times as an extra measure to remind. When those doses are taken, he returns the pillbox to the morning counter when cleaning up after lunch. Nighttime medication is in and on his bedside table, with the supply located in the drawer and daily doses in a pillbox placed on the nightstand.

Routines are critical in organizing medication supplies, dispensing and preparing doses, and remembering to take the pills. They are

<sup>1</sup> All verbal data reported here are careful translations to English.

also the means by which people recall or at least *infer* that they have taken their medications. A person might infer—correctly or incorrectly—that if she executed her normal morning routine, for example, then she probably took her medication. When there is no traceability of past activity in routines, people could benefit—as we will discuss later—from built-in IT support of their existing systems to indicate if pills have been taken.

Routines are how people encode and conceptualize information about their medication. When our participant Ida was introduced to a new system that queried whether she took her medication at 8:00—which, clinically speaking, is only meant to be an approximation anyway, though it didn't feel that way to her—she objected to the formulation of the query. Instead she says in response, “I get up, then I have my breakfast. After that a Helper comes and makes the bed. Then I do the dishes and afterward I take my medication.” Only when prompted further does she add that the time is about 8:30am by the time she takes usually her medication.

Ida's account of when she took her dose is just as accurate as a more temporally exacting report. What matters is that Ida remembers to take her medication every morning at approximately the same time, and that her next dose follows after an appropriate interval. The management of medication is not about outward signs of precision. It is about completion in a timely but not exacting manner, and in the context of the larger rhythms of one's day, and in such a way that continues to enable elder independence.

#### 4.1.3 Conceptualization of Prescribed versus Discretionary Medication

Finally, we found that our participants treat what they call “real” or their prescribed medication differently from other types of drugs (over-the-counter pain relievers) and vitamins and supplements. This is reflected in their spatial arrangements and placements of medication. Karen keeps her “real” medication in the medicine cabinet in the bathroom (the only one of the 10 participants to do so), but keeps her vitamins in the drawer in the kitchen:

*I keep my medication in the medicine cabinet in the bathroom. When I take my medication then I'll take out the pills from the medicine bottles in the bathroom and bring them to the kitchen where I take them with my breakfast. I keep my vitamin pills and Ginkgo-tablets in my kitchen drawer. They are in the drawer because there isn't space in the medicine cabinet. And then, it isn't real medication, even though I take it because I think they work.*

In another example, Kirsten keeps her prescribed medication in her kitchen cabinet by the window. In contrast, her fish oil is kept on her kitchen table, even though she takes her prescribed medications at mealtimes as well.

#### 4.1.4 Private & Public Perceptions of Health

Elders' management of their medications occurs in their homes, of course, and not in the clinical setting of a hospital or nursing home. As such, whether people see their medical conditions and illnesses as appropriate for an audience of visitors, say, works as a backdrop to the ways they manage their medications.

Two contrasting examples highlight how medication might be treated in part by how one perceives one's home. For Peter, management of his health is a central activity in his day. He has his

medications on his coffee table in his living room (Figure 7) and also on a dedicated desk in his bedroom that holds his medications and notepads where he records blood sugar levels. He makes no effort to hide his physical condition, and the systems he has devised to support it are quite visible.



**Figure 7:**  
**Peter's medications and other daily necessities are kept on his coffee table**

In contrast, Anna, who lives in a nicely decorated and ordered home, curiously keeps her supply of medications well out of view in her piano bench. Even more private than the bathroom medicine cabinet (where, interestingly, only one elder in our study kept her medications), the piano bench is more like a hiding place. In a medicine cabinet, one would expect to find medicine, but in a piano bench, one expects to find music books. For Anna, her home is a place to receive visitors where there are no outward displays of compromised health. Her strategies for managing her medications reflect this preference, and relied on only temporal mappings (and therefore completely hidden medication) when it could; she only came to use spatial cues when new medication required dosing out of her natural rhythms. This desire to not have the stigma of assistive aids—in this case, assistive aids in the form of visible, spatial representations of medication dosing—parallels Hirsch et al's findings [17].

There is also the practical matter of what the space of the homes can afford, as well as one's own propensity toward being organized: Another underlying principle for organizing the medication is based on a very practical consideration, and that is the matter of available space. In Karen's case, she explains that if she had to add a new medication to her existing ones, it would have to go on one of the bottom kitchen shelves because there is no room left up top.

Home settings, then, are “imperfectly perfect” in the ways in which tasks like medication management are accomplished. Homes and their supporting information systems are tailorable and open to improvement, enabling residents to iteratively perfect placement of medications and steps in their routines, and to adapt to the inclusion of new medications, and to optimize the placement of some things vis-à-vis the optimization of others (one can imagine someone thinking “I really want my tea THERE, and I'd like my medication close by, so, hmm, it looks like HERE there's space. Let's try that”). To outsiders, the “sense” of organization



may appear imperfect. This has direct consequences to IT support for in-home health, which we will return to later.

## 4.2 The Work of Health Care Workers

Health care workers in the Danish welfare system provide in-home care with frequent visits depending on need. The monitoring of the physical, social and psychological condition of the elderly takes place in the home where the caregivers base their assessment on what they see and hear there. This includes assessment of the physical state of the home and how an elder moves within it.

*It's best if they're in their own home. Then you can get a clearer picture of the person, who they are and get [the care giving] right. (Hanne, Nurse)*

*When you know a citizen it is easy [to see how they are doing] – you keep an eye on if the place is a mess, if there is spill. If there are newspaper advertisements everywhere, or if the kitchen floor is very dirty then it's a sign of things not being the way they're supposed to be. Or if their clothes are sloppy or if there's a mess in the medicine pillbox. Then I'll tell the nurse. There are many small signs that you look for. If you've visited a new citizen and you see that it's a mess and it's dirty then you tell the group leader and talk to the regular helper about it – is this normal or is something wrong here? (Mette, Helper)*

In addition, the health care worker learns the routines and the systems each elder has in place (such as where the linens are stored and how they should be folded). This is driven out of a matter of respect and acknowledgement that worker's workplace is first someone else's home.

*You have to respect their routines and take care of their things even though it can be difficult if they're in a wheelchair to avoid bumping into their furniture [when moving them in it]. (Helle, Assistant)*

*You have to respect that it's their home but it's also my workplace. It's about getting a sense of the home - saying hello properly and not just walking right in and saying that now you have to get an awful lot done in a hurry. (Jette, Assistant)*

This is not to say that health care workers do not impose their own ideas or institutionally-led ways of organizing health-related materials in the elders' homes. This comes to play in the protected residences. The similar apartment layouts invite health care workers to suggest common placement of medication and medical equipment, which largely works to the benefit of the health care workers to help locate items across the many apartments they visit.

Though the intake of medication is done individually, the management of it for elders receiving in-home assistive care is collaborative, although usually over a protracted amount of time. Nurses may help with preparing doses on a routine but infrequent basis (like every third week), and assistants make sure things are in order more frequently (weekly or daily). Helpers might also assist on a daily basis by setting out medication when elders have difficulty remembering to take it. The health care workers provide an external check in the elders' personalized systems. In fact, care staff must learn each personalized system for the elders in their care in order to be able to provide assistance. For each elder, they know the medication is kept in the upper kitchen cabinet next to the tea, or discretely tucked away in the piano bench, or kept readily visible on the kitchen table, ordered bottle by bottle from left to

right. In fact care staff use the state of medications to assess the general state of an elder. Are the usually nicely ordered medications in disarray? Are pills left in the pillboxes? Can the elder still open the plastic-wrapped pre-packaged doses? Management of medication is a cooperative activity that occurs perhaps stretched over time, and in an assistive capacity, with the elder often remaining in primary control.

These qualities of collaboration between elders and health care workers are important to call out, because it is these that would be likely subject to technological innovation. It is also these that are likely to be misunderstood, with the danger being that innovation could control an activity that is squarely in the control of elders currently, and that loss of that control could be quite damaging to the general welfare and feeling of autonomy by elders. Although technological assistance with medication certainly could provide a sense of comfort to the elders and caretakers alike, it is important to recognize that the management of illness remains highly personal—and for some people is highly private. Medication management is also an organizing activity, an ongoing and important task that elders can engage in to help themselves. Technological assistance needs to be analogous and in the form of the same kind of check that health care workers provide now.

## 5 DISCUSSION: DESIGN PRINCIPLES

Our analysis of elder's medication management practices and the means by which mobile health care workers support those practices—in a society with a long tradition of in-home support—suggests a set of design principles to guide development of technological support systems for assistive care. Although our principles are derived from the particular task of medication management and pertain first to this task domain, they speak to a broader perspective of what future assistive technology design might look like.

We begin with a recognition that medication management usually begins before a great deal of outside assistance is necessary—that the “home-made” systems that people put into place are first designed to remind and help themselves with medication intake before health care workers become involved. The **first principle**, then, is for assistive IT to *support personalized medication management systems that can be distributed across the home using spatial arrangements in places that support routines*. These computationally enhanced versions of people's personalized medication management systems need to be *flexible and adaptable* to changing medication and reminding needs, and should be in the form of *physical artifacts, surfaces and containers with built-in computational support*. In other words, these systems still have to remain first and foremost physically manipulable, and secondarily computational. Digital support could build in temporal dimensions (cueing and reminding) to physical artifacts.

This is because, as the **second design principle**, computation should not be viewed as first for the benefit of the clinicians who check for measures of consumption. Designing to track whether people take medication does not necessarily support actual medication intake. Hence, *computation should, as a first-order design goal, benefit elders in the management of their medication*. We believe, however, that the needs of the elders and health care workers can *both* be met if the design is based on the medication management activities of elders. By doing so, not only might it be possible to better support medication adherence, but we believe that it will also provide more accurate intake information for clini-



cians. Additionally, as our research community has learned with other collaborative computational systems, this will increase the likelihood of elders' use of a system, because it provides direct benefit to those using it [15]. Interaction with a technological system that, at its basis, is built on familiar physical artifacts is more manageable by users, and maintains the familiar practice of physically distributing medication across the home.

As a **third principle**, this distributed, modular, and physical-digital system should provide *windows of inference for remote assistance*, windows that can be "opened" as more and more assistance is needed. This mimics the kind of collaboration we observed in home health care, where health care workers "read" the personalized spatio-temporal medication systems to infer how an elder was doing. Health care workers also helped elders adapt the systems with the addition of new medication or dosing patterns, or when seeing when systems fail to accurately remind people to take their doses.

Such an approach is in keeping with our **fourth principle**, that of *technology by invitation*, which speaks to matters of privacy and maintaining personal dignity. If technology is introduced in a stage-wise fashion to people, first as means of supporting their individual capabilities, then—in collaboration and agreement with the elder—"turning on" features that allow for remote assistance and care, elders can maintain control over what happens in their home; they also can participate in decisions about how the management of their health should adjust in time. This is particularly important for people who view health status as a private matter.

The **fifth principle** addresses the matter of the distinction between "real" versus "other" medication. The intake of discretionary medication and supplements, while a serious issue from a clinical point of view, is not always accounted for in IT-based ideas of home health support. We see this reflected in the elders' practices that vitamins, supplements and discretionary medication—unless explicitly prescribed by a doctor—conceptually belong to the category of things that is not under the purview of medical personal. Health care workers who visit homes might very well have knowledge of supplements taken, just by visiting the home frequently. Under a certain threshold, workers might not remark on these supplements because they know that intake of these are not contraindicated. But what of remote IT support that might not have the full view of a person's dietary or health habits? This begs the question, "What is health?" *A high-level design principle for in-home health IT-based assistance needs to conceptualize "health" to be broader in scope than what occurs in the context of a doctor-patient exchange.*

## 6 CONCLUSION

Our work has taken an elder-centered view of medication management, with resulting observations that suggest that an approach to supporting in-home health care and reliable dosing of medication should begin with support for the personalized spatio-temporal systems and routines that people create in the context of their homes. These systems exploit spatial and temporal features in familiar environments, enhancing a person's ability to manage medication even in the presence of partial information. The systems are collaborative, where collaboration occurs between the elder and the environment, the elder and their "future" and "past" selves (in the act of recall and prospective remembering), as well as the elder and in-home health care workers. For the latter relationship, health care workers adapt their work to elders' systems,

and learn to "read" those systems to make inferences about the health and well-being of the elder. They are also the things around which the elder and the worker collaborate to adapt the systems to changing health.

From these observations we introduce five design principles for IT that can help people "age in place." These principles are formulated with the recognition that medication management, as one aspect of self-care, is sometimes a central activity in people's days and can itself serve as an organizing function. We propose that through computational support of these personalized medication management systems, IT can often enhance people's abilities to manage a complex task, and support remote health care assistance without taking away personal control.

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