Contextual Design of a Motivated Medication Management Device

By Erin Chiou, Vindhya Venkatraman, Kathleen Larson, Yaqiong Li, Madeleine Gibson, & John D. Lee

Approximately 80% of Americans age 65 or older manage at least one chronic illness, and 50% manage at least two (Centers for Disease Control and Prevention, 2003; Federal Interagency Forum on Aging-Related Statistics [FIFA], 2012). For people living with chronic illnesses, good health outcomes often depend on self-management and appropriate use of medicines. Although some older adults have caregivers, a significant number live alone and may need to manage their own medication regimen. According to estimates from 2010, 19% of men and 37% of women older than 65 live alone (FIFA, 2012).

To address some of the cognitive and emotional challenges of self-managing complex medication regimens, our multidisciplinary team used contextual design to develop a medication management tool inspired by and grounded in real-world data. Our resulting prototype focused on improving users’ experiences with medication management and encouraging users’ adherence to medication therapy.

Background and Motivation

Many factors influence medication adherence, and increased complexity caused by multiple illnesses and therapeutic regimens can lead to nonadherence (Elliot, Ross-Degnan, Adams, Safran, & Soumerai, 2007; Murray & Morrow, 2004). Medication adherence is also affected by patients’ understanding of consequences and motivational factors. Motivation is a complex process that affects patient behavior in their healthcare activities. Multiple factors have been predicted to affect motivation, including locus of control, self-discipline, value placed on health, socioeconomic factors, self-esteem, social support, information about medication, and therapy (Carter & Kulbok, 2002; Vlasnik, Aliotta, & DeLor, 2005). Here we define motivation as “a force influencing health behaviors” (Carter & Kulbok, 2002), recognizing wide applicability of motivation as a construct.

To aid older adults in their medication regimens, commercial devices are available (for examples, see E-Pill Medication Reminders, 2011). Many of these devices focus on simplifying medication regimens and act as reminder systems, which address several barriers to adherence. However, these devices often fail to improve long-term medication adherence (Foo, Chua, & Ng, 2011). Recent work on medication self-management suggests that a medication-dispensing device adaptable to older adults and the diverse challenges of independent living could help to address the shortcomings of current medication management devices (Hernandez, Sommerich, & Woods, 2011).

To better understand motivation in medication management and adherence, we turned to the actual work of personal medication management. We used contextual design (see sidebar), a method detailed in Contextual Design: Defining Customer-Centered Systems (Beyer & Holtzblatt, 1998), to uncover artifacts, strategies, cultural influences, and intents that influence medication adherence in older adults. On the basis of our data, we developed a software prototype of a medication management device that incorporates motivational factors to encourage and support long-term medication adherence.
Our design team comprised five engineers with backgrounds in industrial engineering, electrical and computer engineering, computer science, mechanical engineering, and psychology. This diversity supported the goal to include multiple perspectives and to have cross-functional representation on the team. The entire design process, from data collection to prototype development, occurred within 4 months. We split into groups of two and three to collect data and reconvened to complete the subsequent design stages.

To collect the data, we employed contextual inquiry, an interview-like activity based on the master–apprentice framework; designers approach the interview as apprentices and watch and learn from the user, who is the “master craftsman” (see sidebar). This approach enabled the design team to observe medication management as it occurred within older adults’ daily routines. More important, participants verbalized their intents at each step, which provided the research team with valuable insights into the intent and motivation behind certain tasks.

For contextual inquiry, it is generally suggested that six to ten people be interviewed for each role in the work practice (Beyer & Holtzblatt, 1998). We initially recruited six participants, but two dropped out because of ill health, and time constraints prevented our recruiting more. We conducted contextual inquiries with the remaining four participants (two male and two female), who were residents of a Midwestern town in the United States. Participants were between 55 and 80 years old; three of them were retired and one was employed. The participants were recruited on the basis of their interest in our project, and given their willingness to discuss their medications and medication routines with us, we considered them a sample of an older adult population willing to talk about their medication regimens.

All participants managed their medications at home, so we traveled there to conduct the contextual inquiries. We took notes and photos (see Figure 1), audiotaped the conversa-
tions, and sketched the physical space during the interview sessions. The participants had complicated medication routines: One had to coordinate health services between two cities; all the participants were on medications that required administration roughly three times a day; and between them, they were taking at least 10 different generic and brand-name pills, eye drops, and vitamins and other supplements. Our focus for the contextual inquiry was to understand the motivational aspects and intents behind medication management and long-term adherence.

WORK MODELS AND DATA CONSOLIDATION

After the contextual inquiry, we occupied a design space to consolidate and interpret the data. In the design space – which consisted of a large flat-screen monitor, bare wall space, and a floor-to-ceiling dry-erase board (see Figure 2) – we could easily display the data and immerse ourselves in a collaborative data review.

We developed work models for each participant’s medication management practice using data from the contextual inquiries. Contextual design outlines five work model types (Beyer & Holtzblatt, 1998), each of which captures one aspect of the work practice:

- The flow model describes the roles, responsibilities, and communication among stakeholders of the work.
- The sequence model exposes the order of tasks and activities.
- The artifact model illustrates the tools used or modified during work.
- The cultural model depicts the social influences of the workplace.
- The physical model outlines the visible layout and movement of work.

We created five models per case, a total of 20 work models, that visualized the work of medication management. Each model type was then consolidated (e.g., the four sequence models were consolidated into one sequence model), resulting in five consolidated models representing our interviews.

Next, we constructed an affinity diagram to organize our insights from the interviews and work models (see Figure 3). The affinity diagram “shows the scope of the user problem: it reveals in one place all the issues, worries, and key elements of work practice relevant to the team’s focus” (Beyer & Holtzblatt, 1998, p. 154). We gathered insights that emerged from contextual inquiry and model building. We then inductively categorized these insights into common findings. Using the same inductive process, we grouped these categories into higher-level categories until we had four levels.

We identified the following major constructs of the work:

- empowerment in health and lifestyle,
- separation of medication,
- strategic placement of memory aids,
- need for timely medication information,
- coordination between self and care network, and
- work environment conditions.

These constructs were central to informing the motivational aspects of our medication management device. More important, the affinity diagram reinforced the perspective that empowerment could be a powerful philosophy to guide device design that is intended to motivate and support long-term adherence behavior. For example, our participants used personalized strategies to maintain health, freedom, and mobility. They also disliked complicated technology that disrupted their lives and desired easier access to medical information and services. To highlight these relationships, we mapped our work model insights to the motivation findings (see Table 1).

Building on our findings, we decided our device would need to serve multiple roles: as an information hub, a medication organization device, and a household object...
meant for display. Although ease of access to information is important for self-education and long-term adherence, we felt that if the device were purely an informational tool, people would be less motivated to use it. Furthermore, our contextual inquiries revealed how older adults remind themselves to take medications in ways that would be inconspicuous to guests – by placing strategic objects in prominent locations but storing actual medication out of sight. To echo this strategy, the device would be aesthetically elegant to warrant public display but commonplace to avoid announcing one’s health status to outsiders.

DEVELOPING VISIONS FROM CONSOLIDATED DATA

The insights gleaned from our data collection and analysis informed our next step: developing visions of an ideal workflow. Our final vision describes a medication management device that facilitates information exchange as a predominant motivational factor. This vision was driven by findings from our flow model, artifact model, and affinity diagram depicting a need for specific information from multiple sources. We also found that self-education and information were particularly important for long-term motivation, which echoes previous findings showing that barriers to medication adherence include a lack of medication knowledge and social support (Foo et al., 2011; Vlasnik et al., 2005).

The cultural model showed that users’ experiences with the technology, particularly tentative attitudes of older adults toward “complicated” technology, must guide the vision for the medication management device. Thus, we also considered details such as how the device would notify a user when to take medication. Our vision is as follows:

The device is attractively designed so the user is encouraged to place it in a prominent location within the home, such as the living room or kitchen. When placed in a visually prominent area, the device serves as a visual reminder for taking medication. The device also stores the medications and would dispense them according to the prescription. The device reminds the user about medication times by visually glowing and audibly chiming, and offers comprehensive medication information in a clear and simple way that supports the user’s information needs. With these basic functions implemented in unobtrusive ways, the device is a useful and engaging object.

As an information resource, the device organizes and aggregates medication information typically dispersed through different channels and formats, such as prescription printouts or Web pages. To eliminate barriers to relevant medication information, the device organizes these resources in one easy-to-navigate system. The user can select a medicine...
Table 1. Main Insights From Our Consolidated Work Models and Affinity Diagram

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<tr>
<th>Model</th>
<th>Insights</th>
<th>Related Motivation Findings</th>
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<tbody>
<tr>
<td>Flow</td>
<td>• Outlined critical information users would need to achieve their work, such as pharmacy instructions, dose adjustments (titration), and refill information.</td>
<td>• Personalized strategies</td>
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<td></td>
<td>• Indicated a complex network of information in prescribing and titrating medication; to facilitate this process, the device should support information flow between users and care providers.</td>
<td>• Ease of access to information</td>
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<td></td>
<td>• Supported the idea that users should have access to medication and therapy information at any time, which is considered important for building knowledge and understanding and which have been identified as key motivational factors (Vlasnik, Aliotta, &amp; DeLor, 2005).</td>
<td></td>
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<tr>
<td>Sequence</td>
<td>• Captured intents of steps taken in the medication regimen process and measures that prevent forgetting a dose; potential breakdowns in daily regimen were mostly attributable to travel or special situations.</td>
<td>• Personalized strategies</td>
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<td></td>
<td>• Showed that users adapted their medication regimen to their daily routine.</td>
<td>• Fit to daily routines</td>
</tr>
<tr>
<td></td>
<td>• Users visually checked the number or color of pills just before administration. They also occasionally checked the amount of medication left in the bottle when they predicted refills were imminent.</td>
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<td>Artifact</td>
<td>• Revealed a persistent medication management tool, the pillbox. These pillboxes were used to store and organize pills by time of day, for a week. One user preferred to store pills in her pillbox by emptying all the pills of one type into a slot, not by day or time.</td>
<td>• Personalized strategies</td>
</tr>
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<td></td>
<td>• Communication from the health system (e.g., the Veterans Health Administration) prompted the user to schedule a checkup or order the next shipment of medication.</td>
<td>• Simple technology, no disruption</td>
</tr>
<tr>
<td></td>
<td>• Half pills were stored in pill splitters, to be taken in the next dose.</td>
<td>• Ease of access to information</td>
</tr>
<tr>
<td>Cultural</td>
<td>• Users relied more on memory and habits, not technologies, such as computers or smartphones.</td>
<td>• Personalized strategies</td>
</tr>
<tr>
<td></td>
<td>• Users did not see themselves as sick and enjoyed living active lives. They felt empowered by managing their therapies themselves, leading us to follow the “motivation through empowerment” perspective for the design.</td>
<td>• Fit to daily routines</td>
</tr>
<tr>
<td>Physical</td>
<td>• Described where users store and administer medications.</td>
<td>• Personalized strategies</td>
</tr>
<tr>
<td></td>
<td>• Medications are mostly stored out of sight (e.g., in cupboards), and a week’s supply is typically transferred to pillboxes.</td>
<td>• Fit to daily routines</td>
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<tr>
<td></td>
<td>• Medications were also placed near a water source or everyday objects (e.g., coffee pots) to serve as reminders for taking night or early-morning medications. These objects were part of an everyday routine, without being prominent or obvious to outsiders.</td>
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by name or image to obtain information on the treatment, dose, side effects, and specifics of the therapy when taking that medication. Ease of use helps to maintain the user’s positive perception of the technology, and usefulness motivates sustained use.

A prominent feature of the design connects the user to social support mechanisms while reflecting personal goals of living an active and independent life. Like a digital photo frame, the device displays the user’s personal photos on the home screen to augment the emotional connection between users and family members separated by distance and to associate medication adherence with living a healthier life. Digital photos have been identified as a means to leverage emotional connections in older adults and the role photographs play in people’s lives (Mynatt, Rowan, Jacobs, & Craighill, 2001). In addition to being a pleasant but commonplace display in the
home, this feature has the goal of serving to remind the user of reasons to maintain good health and to motivate the user to adhere to his or her medication regimen.

When the user is not actively interacting with the device, the screen loops through a stored set of photos from the user’s life. When it is time for the user to take medication, the screen space around the picture glows green. As time progresses and the user has not dispensed the pills, the lights turn to yellow and then to red. In such a case, the photo fades away and reappears when the user resumes the medication regimen. Audio chimes can also act as reminders, based on the user’s preference. By connecting the work of medication management to meaningful goals and relationships, the user receives motivational support for maintaining good health and associates the device with positive past and future experiences.

**DESIGNING THE USER ENVIRONMENT**

Equipped with a vision, we constructed 10 storyboards of different medication management work scenarios to hypothetically test our design. The storyboards, consolidated models, and affinity diagram were then used to inform our user environment design (UED). The UED, akin to the user interface designer’s specification sheet, showed each aspect of the redesigned work practice and how the work flows from one function to another. The UED focused on grounding personal medication management in the intrinsic motivation of users to lead empowered and healthy lives.

Aspects of medication management span multiple roles and systems, including different health-care providers, system developers, and patients. When building our prototype, we singled out focus areas most relevant to user motivation:

1. Reporting medication storage content and information to empower the user to self-manage complicated prescription refill and dosage information.
2. Informing the user of his or her health records and trends.
3. Providing personal, visual medication reminders to subtly encourage an active, healthy lifestyle.

We excluded some important aspects of medication management work from our prototype design, including titration, communication with family or caregivers, information exchange with providers, and travel. Notably, all users we interviewed discussed travel or changes to daily routine as part of their medication management process. We decided these were special work cases tangential to our primary goal of designing for fundamental motivation factors in a daily medication regimen, and that they would be best addressed in subsequent iterations of the design.

<table>
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<tr>
<th>Feedback Description</th>
<th>Integration</th>
<th>Rationale</th>
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<tbody>
<tr>
<td>Illuminate the outer portion of the device, remove explicit warning symbols to prevent anxiety, and keep photo on screen even during alert.</td>
<td>Yes</td>
<td>In line with goal to support a pleasant user experience and avoid anxiety or alarm fatigue. Facilitates a positive reinforcement approach to motivation.</td>
</tr>
<tr>
<td>Change shape of the popup screen for &quot;Side Effects&quot; and &quot;More Information.&quot;</td>
<td>Yes</td>
<td>Turned into dialogue boxes for clarity. Enhances usability for older adults, avoiding interface ambiguity that could lead to frustration and barriers to motivated use.</td>
</tr>
<tr>
<td>Use an avatar [computer agent] to communicate with the user.</td>
<td>No</td>
<td>More research would be needed to determine the effects of avatar features [gender, age, etc.] on user behavior and motivated use.</td>
</tr>
<tr>
<td>Turn the list of medications into individual buttons.</td>
<td>Yes</td>
<td>Made it clearer to the user that the medication names could be clicked on for more information. Enhances usability for older adults, avoiding interface ambiguity that could lead to frustration and barriers to motivated use.</td>
</tr>
<tr>
<td>Add brief drug, dosage, and timing information to the time settings screen.</td>
<td>Yes</td>
<td>Reduces the number of clicks and avoids reliance on memory. Enhances usability for older adults, avoiding navigational ambiguity that could lead to frustration and barriers to motivated use.</td>
</tr>
</tbody>
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**Table 2. Feedback From Prototype Testers Regarding Motivational Features**

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PAPER PROTOTYPE AND USER EVALUATIONS

To test whether our UED described an improved work process, we used paper prototypes. The paper prototypes were hand drawn on sheets of paper or “sticky” notes using colored markers and pencils. They were deliberately “rough” sketches to communicate to testers that the design is an unfinished product and to invite feedback and discussion without overwhelming them with design details. Because the paper prototypes were pieced together with easy-to-assemble materials, the design team was able to respond quickly to impromptu ideas and suggestions.

To broaden the participant pool, we recruited two prototype testers. The testers differed from the original users in location (different city), age (at least 10 years younger), and technology literacy (more exposure to computerized technology). Both were familiar with the work of medication management, in that they self-manage their medication regimens. One of these testers was a nurse who provided a clinical perspective on the design, and the other tester had expert experience in human factors/ergonomics design.

Several key features of our resulting digital prototype came directly from our testers’ feedback on motivational features. Table 2 shows how their feedback was integrated into the final design.

The resulting prototype (Figure 4) relied heavily on our user data. In addition, to support use among older adults who may have limited dexterity and limited patience with technology, we avoided swipe actions, kept button design as unambiguous as possible (e.g., arrow buttons to indicate direction), and minimized navigation in any direction to roughly three clicks or less. Each sheet of paper from the paper prototype represented a page in Adobe Catalyst® CS5.5, which made translating the paper prototype into digital format straightforward. Sticky notes translated to popup windows.

A METHOD TO DESIGN FOR MOTIVATION

Contextual design is an effective method for guiding the design of a work system centered on information transfer among multiple parties, such as helping those in information technology departments to recognize the work practice of the business and to support cross-department system consistency in a company (Beyer & Holtzblatt, 1998, pp. 144–145). As demonstrated in our case, it can also be useful for driving the discovery of less tangible aspects of work, such as aesthetic, affective, and motivational features. The features described in our prototype have not been field tested, but initial feedback from medical professionals and potential users uninvolved with the study has been promising.

We attribute some limitations of our study to the small sample size and our narrowed focus in the UED. We extracted three focus areas from our UED, which limited aspects of our prototype. Prior to further development, we recommend closer analysis of information transfer among pharmacists, physicians, caregivers, and developers – important aspects of medication management we set aside in this version of the prototype.

In this study of medication management, contextual design helped us untangle some of the complexity surrounding personal medication management, appreciate the multiple parts of the care process, and visualize the difficulties device designers face given the distributed elements of the U.S. health-care system. For example, pharmacies may have electronic information systems for storing patient information that cannot communicate with other pharmacies’ electronic information systems. This lack of communication may cause gaps in information or record keeping, especially if patients go to more than one pharmacy because of cost, location, or other incentives. The issues we came across would need to be addressed by health-care policy or other issues that would be outside the control of the designer. Success of a device...
such as ours would need top management support (Beyer & Holtzblatt, 1998), which in this case may extend beyond project managers to health-care providers and policy makers.

REFERENCES


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