The Context-Aware Pill Bottle and Medication Monitor

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ABSTRACT
The video illustrates and critiques a context-aware *pill bottle/stand* that reminds the elderly when it is time to take their medication. A *medication monitor* situated in a caregiver's home displays awareness information about the elderly user's medication compliance.

Keywords
Medication compliance, context-aware appliances.

1. INTRODUCTION
Medication mismanagement is common among older adults [2]. The elderly forget to take their drugs, take incorrect doses or the wrong drug, take them at incorrect times, or terminate drug-taking prematurely if they feel better. Non-compliance with prescribed medication can have serious effects: it causes 125,000 deaths annually in the United States [3]. Health care systems are also economically penalized as they must deal with the patients suffering medication mismanagement effects.

Studies show that "forgetting" is the primary reason behind medication non-compliance [4]. Consequently, various practitioners have developed technology as a way to remind people what drugs they need to take at a particular time. Low technology solutions include pill organizers, where people place pills in compartments corresponding to a scheduling regime. Electronic pill organizers now include visual and audible reminders that goes off at scheduled intervals. MEDPort's MedGlider Talking Reminder (www.medportllc.com) is a standard organizer augmented with a timer that indicates when a pill should be taken through beeping, a voice, or a flashing light. The MD.2 Personal Medication System includes pill dispensing: people load pills into the device; a visual and auditory alarm reminds one of when the drug should be taken, and it automatically dispenses the drugs when the person presses a single button. It can be optionally connected to an on-line support center whose staff monitors medication compliance and alerts caregivers upon non-compliance. The problem is that these devices require people to load the pills into them according to their medication schedule (a large source of error), alarms are fairly generic (which could be confusing), and support services may be unaffordable. We believe the next step in medication management technology is context-aware devices that know about the drug it is dispensing and its medication schedule, customize its messages to fit the elderly person, and collect and display status information and alarms to friends and family as needed.

Our overall goal is to understand the prospects and problems of domestic devices that deliver major benefits yet have potentially severe consequences in situations where they fail. Consequently, we design and critique a context-aware *pill bottle/stand* to remind elderly users when it is time to take their medication, and a *medication monitor* situated in a caregiver's home that displays awareness information about the elderly user's medication compliance. These are described below.

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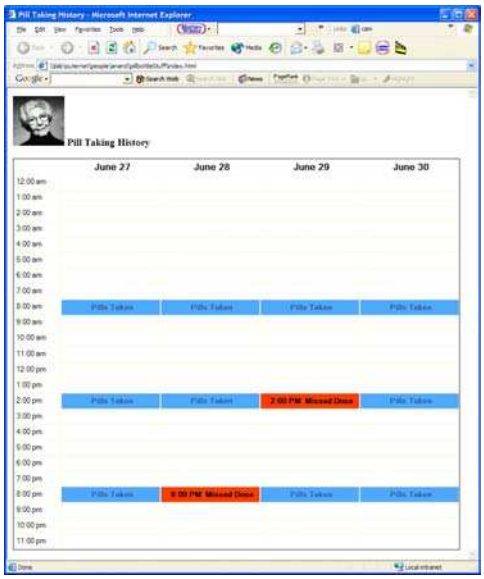
2. DESCRIPTION
The pill bottle/stand, which is placed in the home of the elderly user, comprises two parts. First, standard plastic pill bottles are augmented with RFID tags (Figure 1a): these tags are associated with specific prescription information filled in by a pharmacist and stored in an XML database. Information includes when people should take these medications, special warnings (e.g., pills need to be taken with food), prescription duration, and alerts customized to the patient. In this way the pill bottle carries knowledge about itself. Second, the stand (Figure 1a) contains an RFID tag reader, LEDs, a button, and a network connection to a computer. When pill bottles are placed on the stand, it reads the RFID tag and queries a server's database for regimen information. The stand uses the XML information to reminder the person when it is time to take the pills, and to refill their prescriptions because it is about to run out. When a pill bottle is removed from the stand, it assumes that the person is taking their pills; the stand vocally reminds the person to 'please put back the pill bottle' if it is not replaced in a modest amount of time. Reminders come in various forms, where they gradually increase in obtrusiveness if the person has not taken their drugs i.e., the bottle has not been lifted off the stand.

- *Visual alerts.* The initial signal is a minimally intrusive visual alert of blinking lights on the bottle stand itself (Figure 1a). This works when the person is within sight of the device.
- *Auditory alerts*. The next alert is a modest chime sound, but this eventually changes to a spoken alert detailing the action to be taken, e.g., "it is time to take three pills". These work when the person is close by but not in sight of the device e.g., another room in the house.
- *Text alerts on cell phone*. A text message is sent to the person's cell phone detailing the action to be taken. This works when the person is out of the home e.g., in the garden or shopping.
- *Visual alerts to caregivers*. If non-compliance reaches a level of concern, alerts are sent to caregivers via a medication monitor, described shortly.

1a: Pill Bottle and stand

1b: Montior



1c: Web-based medication summary

Figure 1. Components of the system

The person can also press the button on the stand (bottom of Figure 1) to repeat the last auditory alert, and to probe in depth for more information about what to do and why they should do it.

The second component is a *medication monitor* located in the home of a personal caregiver (e.g., a relative). Inspired by LumiTouch [1], it is embodied as a touch-sensitive picture frame surrounded with LEDs (Figure 1b). An inserted picture associates the device to the pill-taker. When missed medications reach a point of concern, the stand sends a notification to the medication monitor causing the LEDs to blink. The caregiver can act upon this by touching the picture and recording a voicemail message. This message is delivered to the pill bottle stand, which announces its arrival and plays it back when the button is pressed.

Finally, the detailed medication history is accessible on a web site, where professional or personal care givers can graphically review the elderly user's pill taking history (Figure 1c). Missed medications are highlighted in a contrasting color.

3. CRITIQUE

We do not argue that our system is an ideal solution to medication management. Rather, we use it to ground our understanding of general issues surrounding context-aware devices in the domain of the elderly and medication compliance. Several key issues are described below, although more certainly exist.

Heuristic inaccuracy. As with many context-aware devices, end-user intentions and actions are inferred from sensor input. In our case, the device infers that a person has taken the medication when the bottle is lifted off the stand within a specific time window. This heuristic is quite fallible: people may pick up and replace the bottle without taking the drug, or they may take more drugs than expected, or they may take the bottle away with them, or they may take drugs out of the bottle to take at a later time. e.g., when traveling. While other sensors could provide better estimation accuracy (e.g., weight sensors), even occasional errors can result in quite serious consequences.

Trust. The elderly may become overly reliant on the device, where they may trust it in spite of its inaccuracies.

Placement. If the home is large, the elderly or the caregiver may want to move their devices around the home to increase or decrease its salience. If the devices are wired (as ours are), this limits where they can be placed and hinders casual relocation.

Robustness. The device needs to work in harsh settings, e.g., likely placements for the stand include wet areas such as bathroom or kitchen counters.

Annoyance. Alerts may become annoying over time, especially if they are false alarms (due to heuristic inaccuracy) or if they intrude at inappropriate times (e.g., when taking a nap). Annoyance also covers false alarms that worry caregivers.

Confusion. Alerts also have to be clearly understandable, especially for elderly people who are easily confused by ambiguous alerts or by being uncertain about how to respond.

Privacy. There is a fine balance between informing caregivers vs. having them intrude excessively into an elderly person's feeling of independence. Remote alerts must be tuned to this relationship.

4. REFERENCES

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