DigiSwitch: Design and Evaluation of a Device for Older Adults to Preserve Privacy While Monitoring Health at Home

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ABSTRACT
Home monitoring represents an appealing alternative to older adults considering out-of-home long term care and represents an avenue for health care providers to gain decision-critical information about the health and well being of their older adult patients. However, privacy concerns about having 24/7 monitoring, especially video monitoring, in the home environment have been cited as a major barrier in the design of home monitoring systems. In this paper we describe the design and evaluation of “DigiSwitch”, a health informatics technology designed to allow older adults to see what information is collected about them and temporarily cease transmission of data for privacy reasons. Results from a series of iterative user studies suggest that control over the transmission of monitoring data from the home is critical for users’ privacy and that older adult users are able to use DigiSwitch to monitor and direct the collection and transmission of health information in their homes thus providing users with a way to simultaneously maintain privacy and benefit from home monitoring technology.

Categories and Subject Descriptors

General Terms
Design, Human Factors.

Keywords
Privacy, medical monitoring, older adult, home, aging in place.

1. INTRODUCTION
Advances in medicine and technology and improvements in health care access, education and economic resources have contributed to the growing numbers of older adults worldwide. In the United States alone, there are 38.8 million people over age 65 and, if current trends continue, the projected future growth of the older population is expected to reach 88.5 million by 2050 [2]. This is more than 20% of the projected total population in the US.

One key health challenge facing older adults is the ability to live independently. Threats to independent living include inability to perform activities of daily living [23], cognitive impairment [19] [23], functional dependence [23], medical burden [20], and even characteristics of caregivers [7][8]. One hope is that health technologies may be able to reduce or eliminate some of these threats [29]. Specifically, health informatics research can inform the design of systems that give older people the support they need to remain in their home and maintain their independence [27]. In this paper, we focus on the use of health informatics technology in the form of in-home monitoring to support older adults and their caregivers, thus enabling aging in place.

1.1 Benefits of Home Monitoring
There are a number of potential benefits of home monitoring to multiple stakeholders. First, older adults may benefit from home monitoring if it offers them the option to “age in place” rather than move to an assisted living facility. Older adults often prefer to “age in place” for a variety of reasons. Aging in place provides the opportunity to live in familiar surroundings [25] and may also preserve an older adults’ primary financial asset (their home). Caregivers may also benefit when a loved one ages in place because the decision to put a loved one in assisted living is often related to caregiver guilt [7]. Finally, payers, such as family members, insurers and/or taxpayers may benefit because aging in place is often a less expensive option than assisted living [15]. Finally, community members may benefit if the information from home monitoring is used for population level research.

1.2 Concerns About Monitoring
Despite the many potential benefits of home monitoring, there are also concerns. Many barriers to the successful design and use of
health technologies are directly related to privacy. In one large survey, 67% of participants reported that they were “very concerned” or “somewhat concerned” about the privacy of their health records [6]. Privacy is also considered to be a major barrier in the adoption of Personal Health Records [30], which may contain information collected from personal monitoring such as pedometers.

Besides the general concerns over collecting health information using technology, there is a more specific concern about privacy when using monitoring devices are used in a home environment [9]. This may be especially true in a smart or aware home environment where the goal is to create a true ubiquitous computing environment, complete with invisibility [16]. Precisely for the reasons home monitoring may be most especially useful for older adults, because of the context of use (the home), home monitoring may also pose additional privacy concerns. Indeed, many researchers have pointed specifically to the need to understand the impacts on privacy of introducing technology into the home environment [10][11].

When considering health monitoring for use in the home, it is not only important to consider the context of use, the home, but it is also important to consider the age of the user. Although previous research shows that older adults are concerned about privacy in monitored home environments [5][11], they often underestimate privacy risks [1]. One reason older adults underestimate privacy risks may be because they are unaware of what information is being collected about them when they use myriad technologies. Thus, one barrier to overcome in the design of home monitoring technologies is that of transparency.

In addition to underestimating privacy risks, older adults may also have to deal with additional constraints that affect their privacy decisions. For example, older adults tend to prioritize health, safety, independence and their perceived needs for technology over privacy concerns [3]. While older adults may lose relatively less privacy to home health care technology compared to if they move into a nursing home [28], this does not mean that privacy in a monitored home can be neglected. In their original treatise on privacy, Warren and Brandeis characterized privacy as the “right to be let alone” [32]. In a home that is constantly monitored, older adults may feel that they are never in a position to be let alone. Thus, a second barrier a home monitoring system must overcome is that of control. Once a user understands what data are being collected about them (transparency), control can be enabled by allowing the user to determine if and when those data that are collected are shared.

1.3 Previous Approaches to Overcoming Privacy Barriers

In other contexts of use, previous research has proposed approaches to overcoming privacy barriers.

1.3.1.1 Obfuscation

Many approaches to preserving privacy within the home environment involve collecting video data and then augmenting the data in an attempt to obfuscate the activities (e.g., eigen-space filtering) [14]. However, obfuscation techniques have been shown to be insufficient for preserving a sense of privacy among users [25]. In their study of home based video conferencing, Nerstaedter et al. found that there were no levels of obfuscation that both balanced privacy and awareness across all situations.

1.3.1.2 Feedback

The idea that feedback is important in awareness systems (especially media spaces) is not new. Bellotti et al. [4] pointed out the challenges in providing appropriate feedback to users so that users may be aware of the “system’s attention” and questioned how best to direct feedback to “the zone of user attention”. More recently, Tsai et al. [31] demonstrated that providing feedback in a location-sharing application allayed users privacy concerns and increased user comfort levels.

1.4 Our Approach to Overcoming Privacy Barriers

Clearly it is critical to address privacy barriers in the design of home health monitoring systems. Our approach to reducing privacy barriers was threefold. First we recast obfuscation as data type. Because obfuscation has been shown to be an insufficient technique for preserving a sense of privacy [25], we wondered whether collecting different types of data (e.g., video, motion, sleep pattern), rather than simply making one data type less information rich, would reduce privacy concerns. Thus, we designed each prototype in our system (see [12] for a complete description of the ETHOS system) to capture different kinds of information about the everyday activities of an older adult resident. For example, one device captures motion data while another collects video images.

The second prong of our approach builds on existing ideas of feedback (e.g. [4][31]). In our system, we wanted users to be aware of data that were being collected about them. We sought to make the flow of data transparent [33] so users could see what was being collected and transmitted.

Finally, we propose that, in addition to the previous approaches of data type (i.e., obfuscation) and data awareness (i.e., feedback), control over the distribution of data is critical for user privacy. Thus, in our system we put users in control of if and when information about them is collected and transmitted to others (in this case, a distant caregiver). Each prong of our approach is described in detail below.

1.4.1 Data Type

One solution to the problem of preserving privacy when using monitoring systems in the home environment is to transmit data that are rich in some types of information (e.g., safety information), while information-depleted in other types of information (e.g., identity). Arguably, collecting motion sensor data, for example, should be considered less privacy-invasive than collecting video data because motion sensor data, while providing activity level information, does not provide identity information. Indeed, it was found that older adults considered visual sensing data such as images from a blob tracker to be less concerning from a privacy standpoint than video data [10].

In our system we were interested in collecting a variety of types of data to test whether different types of data (e.g., motion sensor vs. video) would result in different levels of privacy concern. Thus we designed three devices that each collected different data types.

The devices include a Presence Clock, a Beacon Strip, and video cameras. The Presence Clock consists of a pair of devices that collect and display presence information using a motion sensor. The form of the presence clock resembles an old-fashioned wall clock but is enhanced with LED lights that illuminate to show presence, as indicated by motion, of a non-co-located user of the
paired device. The Beacon Strip is a dual function device that both assists users in finding their way to the restroom at night and simultaneously gathers sleep pattern data. Sleep pattern data is collected by a pressure sensor placed under the mattress and is visualized as a simple line graph showing the weight in the bed at different times of the day. A flat line would indicate no change in pressure while several peaks would indicate movement while in bed (for example, see Figure 1). Finally, the video camera collects video images from the home of an older adult user. For more detailed description of the devices, see [12].

Figure 1. Visualization of sleep pattern data collected by the Beacon Strip.

1.4.2 Data Awareness
Increasing awareness of what data is collected by home monitoring systems by making data transparent may enhance older adults’ understanding of the potential privacy risks associated with the devices in their home monitoring system. Transparency requires that no data compilation about an individual be kept secret from that individual. While it is implicit that an older adult will be aware that monitoring technology is being installed in their home, we propose that the user must also be able to see and understand what data are being collected about them in order to fulfill transparency.

In our system, we wanted to ensure that users were aware of exactly what data a caregiver would be able to access. In addition, we wanted the content of the data awareness be presented in a way that was easily understandable by the user. We sought to keep data flows transparent [33] to facilitate a sense of participation, rather than a sense of being invaded upon. Thus we designed the DigiSwitch, a touch-screen computer integrated into an everyday object in the home, a digital picture frame. Within the DigiSwitch, we include a “Friend’s View” screen which allows the user to see exactly what their caregiver is seeing, thus increasing data awareness and therefore providing transparency.

1.4.3 Data Control
Trying to determine what information a user considers particularly sensitive has proven to be difficult and seems to be a variable that interacts with the recipient of the information [26][13][22]. In addition, it seems that users have different privacy concerns and sharing tolerance [21].

An alternative approach to trying to determine a priori what things a particular user will find privacy invasive then, is to allow the user to regulate what information is captured and transmitted as they wish.

The key innovation of the DigiSwitch, or digital switchboard (named as a reference to the original switchboard, which controlled which telephone calls went where), is that it gives users the ability to cease transmitting data at their leisure to a particular recipient, thus putting them in complete control over their own health information. An older adult user can control the flow of information collected about them by the devices in their home monitoring system via the DigiSwitch interface.

1.5 Evaluating DigiSwitch: Three Studies
In the remainder of the paper, we present three studies we conducted to evaluate and refine DigiSwitch. First, we present findings from three focus group study designed to elicit perceptions and ideas regarding a central control device for home monitoring systems, such as DigiSwitch. Second, we present findings from a survey conducted with the same participants, related to the technologies they had discussed previously. Third, we describe the development of a DigiSwitch prototype based on these findings. We then present results of a user study that examines whether older adults could use DigiSwitch effectively. Finally, we conclude by suggesting that idea of a mechanism that allows users to maintain awareness of what information is being collected about them and regulate the flow of that information to others may be one potential solution to the barrier of privacy in future health informatics applications.

2. STUDY 1: FOCUS GROUPS

2.1 Participants
Participants were 48 older adults (28 female) between the ages of 53 and 83 (M = 70.02 SD = 7.87) who volunteered to be part of the study. Potential participants were recruited from the local community through flyers and by word of mouth. Participants were not remunerated for their time monetarily, but were provided with a meal during the study.

2.2 Procedure
All participants visited the Ethical Technologies in the Homes of Seniors (ETHOS) Living Lab [17] located on the campus of Indiana University. The Living Lab is a lab inside of a historic home which is equipped with working prototypes of many technologies being tested for use in the homes of older adults. The house also has lab space for user testing, focus groups, and interviews.

Participants toured the home in groups of 6 - 8 people. After a brief tour of the house, participants were participated in a focus group session that lasted between one to two hours. Each focus group session was conducted by a member of the research team. A trained note-taker recorded themes from the focus group sessions. Each focus group session covered three main topics: 1) an overview of the functionality of DigiSwitch, 2) general concerns about the device, 3) privacy concerns.

2.3 Results
The notes taken during the three focus group sessions were examined for thematic content by two members of the research team. Themes that emerged related to the DigiSwitch are discussed below.

2.3.1 Control Over Devices
One overall theme that emerged was that participants wanted to be able to turn devices on and off individually rather than turn off the system as a whole. Participants suggested that the ability to turn off individual devices would increase their ability to manage privacy. One participant suggested that users would want to be able to turn off the video recording device in particular (FG1).
This was in contrast to other devices where it might be preferable for them to be on all the time. For example, other participants suggested that some devices, such as those that merely indicated presence (i.e., presence clock) should be left on all the time (FG1 & FG3).

2.3.2 Simplicity
A second theme that was laced throughout the focus group discussion was the importance of simplicity. Participants stressed the importance of keeping technology simple for older people. Several participants mentioned that a simple on/off mechanism would be more useful than a more complete, but more complicated set up: “on or off would be enough of a choice” (FG1). Participants likened the on/off functionality to familiar models of on/off devices used in everyday life: it should work like a “light switch” (FG3). Finally participants suggested that even if the technology had additional options, older adults might not use them: “There is a limit to how much fine-tuning” older people will want to do. (FG2).

3. STUDY 2: SURVEY

3.1 Participants
Participants were the same participants described in Study 1 (section 2.1).

3.2 Materials

3.2.1 Survey
The survey contained three sets of questions: a set of demographic questions, a set of questions about technology experience, and a set of questions about home monitoring technologies. For the purposes of this study, only questions related to DigiSwitch (a subset of questions about monitoring technologies) will be discussed.

The DigiSwitch questions enquired about participants anticipated use about the DigiSwitch prototype. The questions were posed as follows:

1. “Would you be likely to turn off any of the devices [using DigiSwitch] from time to time?” with responses including “very likely” “somewhat likely” “not likely” “no” and “don’t know”
2. “If you turned a device off, would you like it to re-start automatically at a set time or would you prefer to turn it back on manually?” with responses including “re-start automatically” “turn it on manually” and “don’t know”;
3. “Would you like to be able to keep a caregiver from knowing a device was off?” with responses including “yes” “perhaps” and “no”.

3.3 Procedure
After participating in the focus group, participants were asked to take a survey related to the same technologies they had discussed previously.

3.4 Results

3.4.1 Intention to Use DigiSwitch to Turn off Devices
As shown in Table 1, the majority of participants reported that they would be likely to turn off monitoring devices in their home from time to time to protect their privacy. The largest percentage of participants reported that they would be very likely to turn off at least one device, while very few participants (9%) reported that they would not turn off any of the devices.

Table 1. Turn off monitoring devices in the home?

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Likely</td>
<td>48</td>
</tr>
<tr>
<td>Somewhat Likely</td>
<td>31</td>
</tr>
<tr>
<td>Not Likely</td>
<td>12</td>
</tr>
<tr>
<td>No</td>
<td>10</td>
</tr>
</tbody>
</table>

3.4.2 Automatic Restart of Monitoring
As shown in Table 2, most participants reported that if they turned off a device they would want it to resume transmitting automatically. A little less than a third of participants reported that they would want to manually restart the recording/transmitting while 13% did not know which option they would prefer. One participant created his own option indicating he would want both options (i.e., manual and automatic resume).

Table 2. Automatic resume of transmission?

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic Resume</td>
<td>57</td>
</tr>
<tr>
<td>Manual Restart</td>
<td>28</td>
</tr>
<tr>
<td>Both</td>
<td>2</td>
</tr>
<tr>
<td>Don’t Know</td>
<td>13</td>
</tr>
</tbody>
</table>

3.4.3 Caregiver Knowledge of Device Status
As shown in Table 3, a (slight) majority of participants reported that they would (or perhaps would) like the ability to hide the status of devices from a potential caregiver. 48% of participants reported that they would not want this functionality.

Table 3. Caregiver aware of device status?

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>17</td>
</tr>
<tr>
<td>No</td>
<td>48</td>
</tr>
<tr>
<td>Perhaps</td>
<td>35</td>
</tr>
</tbody>
</table>

4. DISCUSSION OF STUDIES 1 & 2

4.1 Control Over Devices
When asked about whether they would like to have control over the collection and transmission of monitoring data in the home, most participants reported that they would like to have such control. This suggests that in addition to data awareness and data type, data control may be an important aspect of preserving privacy in a monitored home.

4.2 Device Simplicity
Across both the survey and focus group, the idea that an interface to control multiple home monitoring devices must be simple and easy to use was consistent. The majority of participants reported that they would want a device to automatically resume collecting/transmitting after it had been turned off or “paused” for some period of time. This automatic feature could increase device simplicity in that it would not rely on participants to resume after being off for some time. In addition, technology that assists in areas where users have difficulty (in this case with the prospective memory task of remembering to turn a device back on) may be considered easier to use.
In addition, participants felt it was especially important to focus on a simple, easy to use interfaces given the user population. While technology use among older adults has been increasing, older adults still use fewer technologies compared to younger adults [24] and therefore may benefit from especially easy to use designs.

5. IMPLICATIONS FOR DIGISWITCH

5.1 DigiSwitch User Interface

Based on the findings from the user study, we developed a prototype of DigiSwitch (see Figure 1). This prototype is implemented on a touch-screen capable panel PC, which also acts as a digital picture frame. The choice to implement DigiSwitch as a digital picture frame was inspired by two reasons. First, we wanted the device to function both as a normal household object (i.e., digital picture frame) as well as a ubiquitous computing system allowing users to have full control over the home health monitoring devices in their home. Second, we expected that having a device that only served as a digital switchboard might be a privacy risk in and of itself; if a user did not want his or her friends to know that they had a monitoring system in the home, a DigiSwitch interface might give this information away, whereas a digital photo frame would not. The touch-screen capability also removes the need to have extraneous computer peripherals such as a keyboard and mouse.

5.1.1 The Main Screen

![Main screen of DigiSwitch](image)

The buttons on the left hand portion of the screen change the status of all devices and the buttons on the right change the status of each device individually (see Figure 2). The design decision to allow users to control the status of each device individually was driven by findings from the user study. We wanted to give users flexibility while still retaining the simplicity of an on-off mechanism because users stressed simplicity as a key to a successful design. The text on the buttons were changed from On, Off and Hide to Start, Stop and Pause respectively reflecting the familiar Stop-Start-Pause model from other technologies likely familiar to older adults (e.g., VCR, camcorder).

The Start button allows the user to turn on devices, while the Stop button turns off the devices. The Stop function also allows the user to choose how long they want the device(s) to stay turned off before it they are automatically turned back on.

To address the need for simplicity, we created a Spatial View, which allows the user to view the devices according to the space in their home. Previous work in the area of monitoring devices in the homes of older adults shows that users have different levels of privacy tolerance in different rooms of the house [11]. As shown in Figure 3, the devices in Spatial View are organized according to the rooms in the home and the device(s) that are installed in that room is listed under each room. Users can switch between Spatial View and Device View by means of a toggle button.

![DigiSwitch interface showing in Spatial View](image)

The device buttons have a toggle functionality allowing them to be switched on, off or paused; pressing once will change the status to Pause mode and two presses will change it to Stop mode. The background for each button changes color according to the mode the user changes it to; green corresponds to Start, Red to stop and yellow to Pause. We chose these colors because they are analogous to the colors of a stoplight (stoplight metaphor).

5.1.2 The Pause Feature

The Pause feature was designed to provide the user with ultimate control over privacy. Selecting Pause mode will pause the device(s) so that no real time data is collected and transmitted to the caregiver (see Figure 4).

![DigiSwitch interface with all devices paused](image)

5.1.3 Timer

The timer interface was designed to allow the user to set a specified pause time for all devices or for each device individually (see Figure 5). The default Pause time is set to 30 minutes with up and down arrows added to allow the user to easily change the time. When the specified time set by the user expires, the device(s) would return to the On state.

![Pop up alert window when the user pauses a device or all devices](image)
5.1.4 Friend’s View
The Friend’s View panel was designed to allow the user to see exactly what their caregiver is seeing (see Figure 6) thus providing data awareness to the user. Both the user and their caregiver are able to view this screen. However, neither the caregiver nor the older adult can make any changes to the settings from this screen; if the older adult wants to make a change, they must return to the main screen and change settings from there. The background of the friend’s view is blue to differentiate between the user’s own view and their caregiver’s view. There are two buttons at the bottom of the screen; the Main Panel button takes the user to back to their main panel and the Exit button takes the user back to the digital picture screen.

![Figure 6. The friend’s view of DigiSwitch. This is what the caregiver sees on their panel. The user also has access to view this screen.](image)

The stoplight metaphor is used again here; red means the device(s) is/are paused and data is not transmitting, and green means the device(s) is/are on and data is transmitting. However, when a device is Paused, it is not shown in yellow. Instead, the device is shown in green as if it is transmitting data. Remember though, that when a user chooses to Pause a device, the device is not actually transmitting real data. Thus, in the Friend’s View the caregiver is shown archived (faked) data. By allowing the user to see the friend’s panel, they can be fully aware of what data is and is not being transmitted in real time and visualize what information a caregiver would see.

In the next section, we evaluate many of these interface features.

6. STUDY 3: USABILITY STUDY
We conducted a usability study of DigiSwitch with 7 older adult participants. The goals of this study were to determine whether older adults were able to use DigiSwitch to manage their privacy. Specifically we were interested in the following research questions:

1. Task completion: Can participants complete privacy management tasks including access sharing functions and modify device states?
2. Comprehension: Did participants understand the visual representations and metaphors used in the prototype?
3. User Preference: What were users’ preferences about control panel options including setting timers, view options, and pausing vs. stopping?

In terms of task completion, we were interested in whether users were able to access device functions, including access the DigiSwitch interface from the initial screen, access the view that a caregiver would see, alter the state of each device (e.g., Start, Stop, and Pause all devices; and turn off only one device, turn on only one device, and adjust the amount of time a device (or devices) is/are to be paused.

In terms of comprehension, we were interested in assessing how well the visual representations and metaphors we chose for DigiSwitch were initially understood by users. Our goal was to make the interface immediately usable by participants, thereby requiring little to no training upon installation. Specifically, we were interested in assessing whether participants recognized what each icon represented, understood the state of each device upon initial inspection, understood what information was shared and who had access to the shared information; and understood the red/yellow/green stoplight metaphor.

Finally, in terms of user preference, we were interested in understanding user preferences with respect to setting a time for a device to return to the sharing mode versus setting an amount of time after which the device would return to the sharing mode; preference for a “room view” or a “device view” (described in Section 7.3.2); and preferences about ceasing transmission (both temporary and permanently).

6.1 Method
6.1.1 Participants
Participants were recruited from an existing database of older adults who had previously expressed interest in participating in research studies. Of the 7 participants, 4 were women. Participants were between the ages of 67 and 84 (M = 73.57 SD = 6.32). All participants lived independently in their own homes, and reported that they used computers and the internet frequently. Despite reports of frequent use, participants reported different levels of skill with using computers (see Table 4). Three participants reported experience using a touch screen device while 4 participants reported no experience using a touch screen device.

<table>
<thead>
<tr>
<th>Reported Computer Skill</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginner</td>
<td>1</td>
</tr>
<tr>
<td>Intermediate</td>
<td>4</td>
</tr>
<tr>
<td>Advanced</td>
<td>2</td>
</tr>
</tbody>
</table>

6.2 Materials
6.2.1 Prototype
The goal of the initial prototype was to create a touch screen interface that older adults could use to control monitoring devices in their home. The first iteration (v1 – described above in Section 3.1) was informed by a focus group study, and the final iteration (v2) was informed by the current study.

6.2.2 Procedure
All usability study sessions were conducted at the ETHOS house at Indiana University [17].

First, participants gave informed consent. Next, participants were given a tour of the home. During the tour, participants were shown the devices described in Section 1.4.1 (Presence Clock, Beacon Strip, and video camera) and given a brief description of how each device worked. Next, participants were seated at a table in the living room of the ETHOS house. The moderator introduced the goals of the study and explained the general procedure, and instructed participants to interact with the
7. RESULTS AND DISCUSSION OF USABILITY STUDY

For ease of presentation and discussion, results are presented by research question.

7.1 Task Completion

7.1.1 Could Users Access Device Functions?

Access to control panel interface. No users had problems touching the personal digital photo to elicit the main control panel screen.

Access to the view that a caregiver would see. While most users did not have trouble touching the Friend Panel button (see Figure 2) to access the view that a caregiver would see, one participant was confused as to how to access the caregiver’s view. Instead of touching the button to access the Friend Panel, he touched the Spatial View button. When the prototype screen showed the Spatial View with the devices arranged according to the home spaces (that would have appeared given this selection), he touched the Room View button. Although other users did not experience similar problems, other participants did express related concerns: one user expressed that using the caregiver’s name instead of just “Friend Panel” would make it more personal and thus more memorable and immediately obvious that this button would lead to the caregiver’s view.

Altering the state of one device. All participants were able to stop and start devices individually by pressing the icon within the device frame.

Based on the successful completion of all device state altering tasks, this portion of the interface was retained in the final version.

7.1.3 Could Users Adjust the Amount of Time a Device Was Paused?

In the initial design, as shown in Figure 4, once the participant pressed Pause, an alert was displayed asking the user for confirmation of a default time setting (30 minutes).

![Figure 8. The new alert window for adjusting pause time.](image)

Although we did not measure the precise time on task, users spent an inordinate amount of time reading this dialogue as compared to other tasks, and were confused about whether to press yes or no in response to the dialogue. As a result of this difficulty, we removed the alert screen altogether and instead provided users a screen with a default pause time of 30 minutes, which was adjustable at their preference (See Figure 8).

7.2 Comprehension

In this section we examine how well participants understood aspects of the interface.

7.2.1 Device Names

Despite being shown the Beacon Strip during the tour of the house (where the tour guide called the device the Beacon Strip), two participants did not realize that the Beacon Strip was the device designed to light their path to the restroom at night. Based on this feedback, we changed the name of the beacon strip to Nightlight.

7.2.2 Icon Recognition

Two participants expressed that they did not understand what the lighthouse icon had to do with the Beacon Strip. Based on this feedback, we changed the icon for the beacon strip to a light bulb to coincide with the name change from Beacon Strip to Nightlight (see Figure 9; see also 7.2.1).

![Figure 9. The beacon strip icons. (a) Old beacon strip icon; (b) new beacon strip icon.](image)

Finally, we changed the exit icon from a large red X to an arrow pointing through a door (see Figure 10) because 2 participants...
thought that pressing the X would turn off the DigiSwitch completely.

![X](a) ![DigiSwitch](b)

**Figure 10. The exit button icons. (a) Old exit icon; (b) new exit icon.**

### 7.2.3 Intuitive Understanding of Device State

Upon initial inspection of the device frame, all participants but one were able to immediately understand that all devices were on (see Figure 1). The one participant who did not understand upon immediate inspection, did understand after she saw the second screen (which contained paused devices indicated by the color yellow – see Figure 3). Because all participants were able to understand the device state with minimal interaction with DigiSwitch, we did not make any changes to the device state display.

### 7.2.4 Understanding of Shared Information

When shown the Friend’s View, all participants were able to articulate that the information being displayed to them was the same information that a caregiver would be able to see. The one area of confusion on the friend/caregiver view was how to return to the main screen. Participants were unsure whether to press My Panel or Exit. Based on this confusion, we changed the name of the button to return to the main screen from Main Panel to My Panel (see Figure 11).

![Friend’s View](a) ![Caregiver’s View](b)

**Figure 11. The new version of the caregiver’s view. This view shows the user exactly what the caregiver/friend sees on their panel.**

Similar to the change we made in “access to what a caregiver would see” as described in Section 6.1.1, we also changed the hard coded title Friend’s View to the more personalized <caregiver>’s View.

### 7.2.5 Stoplight Metaphor

All participants easily understood the stoplight metaphor and were able to explain that devices were on when the background was green, paused when the background were yellow, and off when the background was red. Based on this finding we retained this metaphor.

### 7.3 User Preference

#### 7.3.1 Pause “For” vs. Pause “Until”

We tested two alternative default Pause function dialogues. The first dialogue was a Pause For dialogue (see Figure 8) where the user could control the amount of time the device or devices were paused using number of minutes. The second dialogue was a Pause Until dialogue (see Figure 12) where the user could set a specific time at which they wanted the device or devices to resume transmission.

![Pause Until Dialogue](a) ![Pause For Dialogue](b)

**Figure 12. The “pause for” dialogue. The arrow up and arrow down buttons allow the user to adjust the hour and minute. The user pressed either the AM or PM button to select.**

Regardless of which dialogue they encountered first (we counterbalanced dialogue introduction), all participants preferred the Pause For to the Pause Until dialogue. Participants reported that they did not want to have to check a clock to determine the current time in order to utilize the pause function and thought that it would be easier to simply input how long until they wished devices to resume transmission.

#### 7.3.2 “Room View” vs. “Device View”

During the focus groups, participants expressed that they liked being able to control each device individually, rather than having to turn on/off all devices. Thus, we developed an interface to allow users to turn off individual devices by device and by room.

**Removed unused rooms from device view.** In the initial iteration (see Figure 1) of the Device View, the interface showed all devices in the users home. In the case where a device was not installed in one of the default rooms, the room title was grayed out. However, 3 participants tried to press the grayed out rooms to, we assume, toggle the devices in said rooms to Start, Stop or Pause (see Figure 1). So, in the final version, we removed rooms where no device was installed.

**Figure 13. Device view. Devices are arranged according to the type of device.**

We also tested two alternative default device frame views. The first device frame was “device view” (see Figure 13). In the device view, the buttons are arranged according to the type of device. On the other hand the “room view” (see Figure 14), the buttons are arranged according to the space in the users’ home (in other words, by room). Participants were able to use both device frame view successfully.
When showing users the initial device frame, we counterbalanced room view and device view. Regardless of device frame view, participants preferred the view they encountered first (so, if Mary saw room view first, that was the one she reported she preferred). Based on this finding, we determined that the room view and device view were similar in terms of usability and preference, and thus needed a different criteria for choosing which view to use in the final version. We examined existing literature on privacy in smart homes, and found that previous formative work showed that participants expressed the desire to be able to control devices in specific rooms of the house [5][11], thus we chose the “room view” as the default view for the final iteration. Device view is also available as a tabbed selection (see Figure 14).

7.3.3 Digital Photo Frame to Panel Transition
As described in Section 5.1, DigiSwitch usually functions as a normal digital picture frame, with a rotating display of personal photos. In our initial prototype, we designed the photo frame such that DigiSwitch screen would appear when motion was detected near the screen.

However, during usability testing, users resisted this idea for privacy reasons. Users stated that they would not want the panel screen to be automatically displayed when motion was detected because they worried someone other than them would create motion near the photo frame, and therefore trigger DigiSwitch screen and become aware of the dual purpose of the device. Rather, participants said they wanted to be able to access DigiSwitch, but keep visitors to the home unaware that DigiSwitch existed.

In light of this finding, we redesigned the photo frame transition to be an “on touch” transition instead of an “on motion” transition. Therefore, only a user who touches the photo frame will see DigiSwitch interface.

8. CONCLUSION
In this paper we describe the design and evaluation of DigiSwitch, a device to allow a health informatics technology designed to allow older adults to see what information is collected about them and temporarily cease transmission of data for privacy reasons. Overall, we found that users were able to complete most privacy management tasks; understand many of the metaphors, names and states in the device; and preferred pause for, were ambivalent about room view vs. device view and resisted hiding information from caregivers. Our results suggest that older adults may be able to use a control panel device to successfully manage their privacy in a home equipped with health monitoring equipment.

8.1 Contribution
The contribution of this paper is three-fold. First, we described the design of a suite of technologies for monitoring the health and well being of older adults in their homes. Second, we present control panel, a complementary device that allows users to both maintain awareness of what information is collected and regulate the flow of information to others. Finally, we present the results from a user study suggesting that older adult users are able to use DigiSwitch effectively. Thus, the system may provide older adults’, their caregivers, and healthcare providers with a way to monitor at-home health while simultaneously maintaining privacy.

In addition, the work described here has implications far beyond the design of a monitoring system for use in the homes of older adults. More broadly, the work described here is a key first step in designing all sorts of privacy-enhanced ubiquitous health monitoring applications. A key element of such system is providing usable privacy management options specifically designed for the user population.

8.2 Future Work
In the future, we are interested in deploying the ETHOS suite of devices to assess usability, effects on privacy, and effects on older adult caregiver relationship in an in situ study.

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10. REFERENCES