

## Technology and Long-term Care (TLC): A pilot evaluation of remote monitoring of elders

Sheri Reder PhD MSPH

Health Services Research and Development Center of Excellence,  
VA Puget Sound Health Care System, Seattle, WA 98101, USA, and  
Department of Health Services, School of Public Health and  
Community Medicine, University of Washington,  
Seattle, WA, 98195-7660, USA  
E: Sheri.Reder@va.gov

Gwen Ambler MPH

Health Services Research and Development Center of Excellence,  
VA Puget Sound Health Care System, Seattle, WA 98101, USA

Matthai Philipose, PhD

Intel Labs Seattle, 1100 NE 45th Street, 6th Floor, Seattle, WA  
98105, USA

Susan Hedrick, PhD

Health Services Research and Development Center of Excellence,  
VA Puget Sound Health Care System, and Department of Health  
Services, School of Public Health and Community Medicine, Uni-  
versity of Washington, Seattle, WA, 98195-7660, USA

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**Purpose of the study** To conduct a pilot implementation and evaluation of how a new sensor technology for remote monitoring of elders can support elders living at home. **Design and Methods** The study population is community-dwelling elders and their family and/or paid caregivers. The technology was installed in twelve elders' homes. For three months the sensors monitored four activities (meal preparation, physical activity, vitamin use, and personal care) and conveyed summary information to the elder, family caregiver and/or paid caregiver. This study evaluated the use of and satisfaction with the technology, change in the elders' perceived safety and well-being, change in elders' and family caregivers' communication patterns, and change in family caregiver burden. **Results** All subjects used the technology, would recommend it to others, and were generally satisfied with the technology. Elders and caregivers used the technology as a passive alert system, a reminder for elders to conduct daily activities, and as communication enhancement. Elders reported an increase in their perceived safety, well-being, peace of mind and independence. Family caregivers also reported an increase in their peace of mind. An absence of privacy issues and good usability facilitated user satisfaction while intermittent mechanical and software problems were identified as barriers. **Implications** The remote monitoring technology has promise for supporting elders in independent living situations. A study with a larger sample size and fully operational equipment should be conducted prior to large scale implementation. A cost analysis of our technology for long term care is also recommended.

**Keywords:** Long-term care, health care technology, activities of daily living

A high percentage of individuals' life-time healthcare costs occurs at or near the end of life<sup>1</sup> and an increasing percentage of overall healthcare money is being spent on elder care, including long-term care<sup>2</sup>. Long-term care can be defined as the range of institutional and home and community-based services (HCBS) that support individuals needing chronic care. Nationally in 2005, \$130 billion was spent on institutional care and \$77 billion on HCBS<sup>3</sup>.

Most recipients of long-term care want to live in the least constrained manner possible with safety becoming increasingly important as people age. Use of HCBS offers more independence and privacy than institutional care<sup>4</sup> and consumers voice a strong preference for HCBS<sup>5,6</sup>.

Nearly 80% of adults who receive long-term care services at home receive those services from an unpaid family caregiver<sup>7</sup>. They provide care ranging from occasional chores, to making arrangements from a distance, to 24 hour care<sup>8,9</sup>. Although providing unpaid family care can offer benefits to the caregiver, such as supplying a purpose in life<sup>10</sup>, it is commonly acknowledged that caregiving is stressful and can lead to caregiver depression, a decreased sense of well-being, and physical health problems<sup>11</sup>. Increasing family caregivers' ability to cope with the stress of caregiving is essential to keeping elders in non-institutional settings.

One approach to support independence for those who need long-term care is the use of new sensor technologies. A variety of 'smart home' sensor-based technologies and wearable mobility monitors have been developed in recent years<sup>12</sup>, including a sensor system developed by Intel Labs that helps a person and his/her caregivers track activities of daily living<sup>13</sup>.

We conducted a pilot evaluation of a sensor technology under development by Intel Labs, referred to as TLC – technology for long term care. The purpose of our research

is to identify how TLC can support elders living independently.

## METHODOLOGY

### Study design

This was a one year longitudinal pilot study conducted with subjects identified by three Seattle-based elder care programs. TLC was available to subjects for three months following installation. The overall study design was a single group (with participating dyads or triads of an elder and a family and/or paid caregiver) pre-post design. There was one data collection point pre-introduction of the system and two data collection points post-installation.

### Remote Monitoring

Sensor technology, developed by Intel Labs, was used to remotely gather information about the daily activities of community-dwelling elders and provide summaries of four monitored activities to elders and their family and/or paid caregiver. The sensor technology consisted of a wireless bracelet, postage-stamp-sized Radio Frequency Identification (RFID) tags, and matchbox-sized battery-powered wireless shake sensors. RFID tags were attached to small objects with a single natural hand-grasping surface, such as a toothbrush. Wireless shake sensors were attached to larger objects, such as a refrigerator door. The wireless bracelet contained an accelerometer sampling at 100Hz capable of monitoring fine motions of the wrist and an RFID tag reader that could detect the presence of RFID tags within 20-30cm.

Taken together these sensors reported two kinds of data about human activity. First, the accelerometer reported the acceleration of the wrist. Second, the RFID tags and the shake sensors reported on the use of the objects to which they were attached. All reported data was sent wirelessly to a computer in the elder's home. Activity recognition algorithms processed the data and inferred activities performed by the elder.

Given the wrist acceleration data and the object-use data, simple statistical algorithms inferred four kinds of elder activity:

# Remote monitoring

- (i) Movement/physical activity – is the elder moving about?
- (ii) Personal care – is the elder engaging in normal daily activities such as brushing teeth, combing hair and shaving?
- (iii) Food preparation – is the elder preparing food at regular intervals?
- (iv) Vitamin use – is the elder regularly taking his/her vitamins?

Inferred activities were communicated via the Internet to elders and their family caregivers via electronic picture frames in each of their homes that displayed summary information for the past hour, day and week. Paid caregivers could view the picture frame screen when visiting the elder. Study subjects were given a written instruction manual and the use and interpretation of the picture frame screen data was carefully explained at the time Intel research staff installed the equipment.

All displays were updated roughly once an hour with current information about the elder. The displays were adapted from commercially available digital picture frames and were uploaded with rotating background pictures of landscapes and pets. Intel Labs developed and monitored the statistical algorithms, furnished and installed the equipment, ensured the safety of the equipment, and handled and tracked equipment maintenance and repairs.

## Target population

The target population was community-dwelling elders and their family and/or paid caregivers. Recruited elders had to be over the age of 55, at home alone during the day on at least four days of the week, living in the Seattle area, receiving assistance with at least two instrumental activities of daily living, and able to independently perform at least two of the four activities monitored in this study. All needed a family or paid caregiver living in the Puget Sound area.

Family caregivers were defined as a spouse, adult child, friend or neighbor who provid-

ed unpaid care in the form of checking on the elder via telephone or in-person at least once a week. Paid caregivers were defined as those providing or supervising paid long-term care services to the study elders.

## Recruitment

Three local organizations were selected as study recruitment sites to access elders with a wide range of socioeconomic status, care needs, and long-term care services rendered. The Site Investigator from each participating organization (ElderHealth Northwest, Providence Elder Place, or Swedish Home Care) made the initial identification of elders who fit study selection criteria. The site investigators assessed potential subjects' eligibility and determined their interest in participation. A study researcher confirmed their interest in participating and scheduled the initial enrollment appointment and baseline interview. All participants completed written consents for study participation and all procedures and forms were approved by the human subjects review boards at the University of Washington and, when applicable, the referring programs.

Elders were provided with grocery store gift certificates after the baseline interview, one-month interview, and equipment removal. The gift certificates totaled \$575 for elders and \$250 for family caregivers if they completed the study. Paid caregivers did not receive any compensation for participation.

75% of the eligible elders identified by site investigators chose to participate in this study. Of those who enrolled in the study, financial compensation was listed as at least a partially motivating factor for study participation by a quarter of the elders and a third of the family caregivers.

Twenty-six people completed the study: 12 elders, 6 family caregivers, 6 paid caregivers and 2 service managers of the recruiting programs. Three people withdrew from the study: one elder due to a medical emergency and two paid caregivers due to time constraints.

# Remote monitoring

All of the elders who enrolled in the study lived at home alone (*Table 1*). They represent a range of socioeconomic characteristics, with two-thirds living in subsidized housing and three-fourths receiving Medicaid-covered services. One third of the elders needed help with 5 of the 6 instrumental tasks of daily living on the screening tool. Meanwhile, 5 elders (41.7%) could perform all 4 of the technology-monitored activities without assistance.

After a study researcher conducted a baseline interview, Intel research staff installed the technology (a picture frame display, sensor bracelet, and wireless internet system) in elders' homes using both object inventory and equipment installation visits. Intel study team members also installed a picture frame display in each family caregiver's home and service provider manager's office. All subjects were given a lay language manual describing the TLC technology, how to use it and how to interpret the picture frame

screen information. Intel staff went through this manual with each subject, reviewing the meaning behind each icon on the picture frame display and instructing the subjects how to operate the equipment (including using and recharging the sensor bracelet).

## Data collection

Data collection primarily consisted of in-person and telephone interviews. The in-person interviews were held in the homes of elders and family caregivers and at the paid caregivers' place of work. All in-person and telephone interviews were conducted by a study researcher experienced in conducting qualitative interviews. Each interview used a structured questionnaire that included a mixture of open-ended questions and questions with categorical responses. Some questions with Likert scale ratings were also used in the baseline and three-month in-person interviews. Responses to interviews were hand-written on forms by the interviewer, with open-ended responses noted using informal shorthand to record the subjects' phrasing as closely as possible. The study equipment was removed from the elder's home, family caregiver's home, or manager's office after the final outcome evaluation.

*Table 1. Descriptive data of 12 elders who completed the study*

	Description	# (%)
Gender	Female	8 (67)
Recruitment site	ElderHealth NW	6 (50)
	Providence elder place	3 (25)
	Swedish home care	3 (25)
Housing	Private pay	4 (33)
	Subsidized	8 (67)
Services	Private pay	4 (33)
	Medicare coverage	5 (42)
	Medicaid coverage	9 (75)
Assistance received	Personal hygiene	7 (58)
	Housework	11 (92)
	Transportation	8 (67)
	Meal preparation	8 (67)
	Handling finances	2 (17)
Performs without help	Medications	8 (67)
	Meal preparation	11 (92)
	Ambulation	12 (100)
	Personal care	8 (67)
	Vitamins / medication	8 (67)

## Baseline in-person interview

At the baseline interview visit, a researcher described the study, answered any questions and conducted the informed consent process. Baseline information was then collected, including the subject's reasons for participating in the study and current communication/social interaction patterns between the elder and caregiver. For family caregivers, an assessment of their caregiver burden was also performed using the short version of the Zarit Burden Interview (ZBI) scale<sup>14</sup>.

## One month post-installation telephone Interview

After the system was in-place for one month, a researcher conducted a brief telephone interview with each subject to assess his/her interim satisfaction and any changes in communication/social interaction patterns. These interviews were intended to confirm

# Remote monitoring

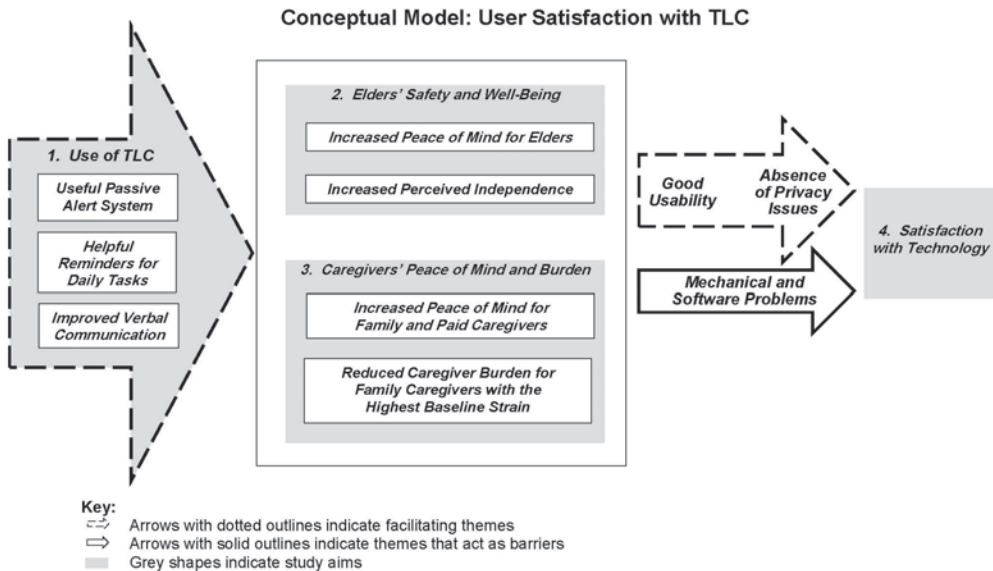


Figure 1. Conceptual model: User satisfaction with TLC

that the system was working well and identify any technological or implementation problems.

### Three month post-installation in-person interview

After the technology was in place for 3 months, a comprehensive outcome interview was conducted with each subject. The interview addressed satisfaction with TLC including utility and perceived accuracy of the information and privacy concerns. Communication patterns among elders, family, and paid caregivers were discussed, as was elder independence and user peace of mind. Caregiver burden was assessed using the short form of the Zarit Burden Interview (ZBI)<sup>15</sup>.

### Data analysis

Our findings are primarily qualitative in nature and formed from content analysis of the subjects' responses to the three interviews. Two study researchers reviewed and loosely coded all the subjects' responses. The study team developed salient themes from these codes and continued to revise the themes and sub-themes until the team felt they accurately reflected the interviewees' responses within the overall context. These themes were then organized into a relational chart,

linking each theme and sub-theme to the study aims with causal directions. In addition we calculated descriptive statistics from subjects' responses to quantitative questions.

## RESULTS

The relationships of the identified themes and sub-themes to each other and the study aims are represented in a conceptual model (Figure 1). Each theme is described in more detail below.

### TLC use

All of the subjects reported using the technology regularly. Every elder routinely wore the sensor bracelet and 10 out of 12 elders usually took off the bracelet only once a day to recharge the battery. At both the one-month and three-month interview all elders and family caregivers reported referring to the display screen daily. The paid caregivers referred to the display screen every time they were at the elders' homes, between 2 and 5 times a week.

Subjects reported using the data supplied via the picture frame screen in three primary ways: reminders for the elders' daily tasks, a passive alert system, and a way for improv-

# Remote monitoring

ing verbal communication between elders and caregivers.

## *Reminders for daily tasks*

Having reminders for daily tasks was part of most subjects' initial interest. An elder summarized her interest by saying that her son could use it to check up on her. Previously he couldn't do that because he, "can't check up on me during the day while he's at work—he's not going to tell his coworkers, 'Hold on, I need to go call my mother to take her medicine'—so maybe this [technology] could help with that". The family and paid caregivers thought the extra information they had about the elders' activities could be useful in ensuring that the elder was performing necessary tasks.

At the 3 month interview, in unprompted comments half of the elders mentioned that the system helped remind them to do something or to create a schedule. 8 of 12 elders rated an 8 or higher on a 1 to 10 scale (with 10 being "very helpful in reminding me to do things") when asked specifically about satisfaction with the technology (*Table 2*).

Elders were most frequently reminded by the display screen to brush their teeth, take their vitamins and eat something. A typical account of TLC as a reminder is: "It reminds me—'hey, I didn't take my vitamins today.' It gets me in a better habit. Sometimes I'll forget to brush my teeth at night after having a snack, but I can see that I didn't brush my teeth on the screen and then I'll go do it".

Another elder explained how she appreciated being aware of her activities through TLC, "It's been interesting to observe myself and see what I'm doing. I'll think about things a little more...It's helping me learn how to pace myself. It helps me be objective".

## *Passive alert system*

The technology was not set-up to provide active emergency alerts or warnings, but rather the system passively provided information on the display screen to assist users in making decisions. Family caregivers appreciated knowing if the elder was 'up and moving around'. One elder articulated how TLC could alleviate the common fear of not being able to get help when it is most needed: "Before I had a pacemaker put in, I had an episode in bed. I had a Lifeline sensor, but I couldn't move a muscle to use it...I was there for 12 hours. This [technology] seems like it could help prevent that situation from happening again".

During the course of the study, all 6 of the family caregivers used the system as a passive alert system when the display screen showed an unexpected lack of activity. The 6 elders with family caregivers liked this function of the technology. A typical comment from an elder was, "If I'm not walking or eating, my son knows to call in and check. I could be lying on the floor and need help". Family caregivers responded in a similar manner, "With the monitor, I can watch what he's doing and I don't need to be here [at the elder's home]. If he's not on

*Table 2. Three months TLC satisfaction ratings on a 1 (worse)-10 (best) scale; n=12*

Item	Median (range)		
	Elder	Family caregiver	Paid caregiver
Learning to use the technology	9 (5-10)	10 (9-10)	9 (5-10)
The accuracy of the information provided	8 (7-10)	8 (5-8)	8 (7-9)
Helpfulness in reminding things to do	8 (1-10)	9 (2-10)	6.5 (3-10)
Increase of peace of my mind	10 (5-10)	9.5 (7-10)	8 (3-9)
Feelings about safety about elder living alone	10 (5-10)	9 (7-10)	9 (8-10)
Privacy of the information about the elder is well protected	1 (1-3)	1 (1-1)	2 (1-3)

the monitor and not answering the phone, then I can come here”.

One elder had an episode where she went to the hospital over the weekend and her service provider manager didn't know. This manager was alerted to call her and check-in when there was no activity on her screen from the weekend. The elder in question expressed her gratitude for the back-up system of TLC, “The time I was sick and away, I didn't know so many people would be so concerned it wasn't registering... It made me feel great, because I could have been here sick. I could have been here dead”.

## *Verbal communication*

*Elder and family caregiver:* All 6 family caregivers noted a positive change in their verbal communication with the elder. Depending on the situation, positive changes were sometimes experienced as a result of increases or decreases in verbal communication.

Three of the 6 elders with family caregivers reported talking on the phone with their caregiver more frequently during the course of the study. A typical comment from elders whose verbal communication increased was, “I've enjoyed the connection it's made between my sister and me...I think it's made us closer. She'll call me up more now...It's made her notice more what I am and am not doing”.

In other cases fewer phone calls took place. The calls eliminated were typically routine checks to make sure the elder was alright—the types of calls that were often perceived as annoying or “intrusive”. Family caregivers explained how the system eliminated the need to “disturb” the elder for some routine phone calls, “You can see from the display what she's been doing. In a lot of respects, you didn't have to call as much. It facilitates both of you knowing when you don't have to worry about it and when you do”. Another family caregiver mentioned that, “It's nice not to have to make a phone call every morning so I don't start off ‘ruining’ her day”.

*Elder and paid caregiver:* Neither the elders nor the paid caregivers noticed a change in the frequency of their communication during the study; however, paid caregivers felt they had accurate information about the elders' behaviors. One paid caregiver reported, “I got to know if [the elder] was telling the truth, because I could find out from the computer”. Half of the paid caregivers stressed that the benefits of technology should not substitute for the “human touch” of providing care, because the system “can't show what the people are feeling”. One paid caregiver explained that “something older people need a lot is social interaction, so it would be bad if this type of system would replace caregivers seeing the person in the home”.

## **Perceived safety and well-being**

The multiple uses of the information provided helped increase elders' perceived safety and well-being as illustrated by an enhanced sense of independence and greater peace of mind.

## *Independence*

All of the elders lived alone and many described their desire to remain in their own home. Unprompted at baseline, four of the twelve elders described their underlying interest in the technology as a way to help them remain independent. One elder explained how she hoped the system would help her by saying, “It'll give me a schedule...It's very critical that I do everything right to live on my own”.

During open-ended responses after using the technology, half of the elders mentioned the technology increased their feeling of independence. Three of these elders felt a sense of satisfaction being able to track their own activities. One woman expressed the feelings of independence the technology gave her by saying, “When I look at it, I feel satisfied. ‘I did it. I did it on my own’”. Another 3 elders felt the information from TLC helped their family or paid caregivers realize how active they were. A typical sentiment

among these elders was, “[My caregiver is] concerned about me and thinks I don’t get up enough, but now she can see the feet and know I get up and move around”.

Family caregivers liked the balance between having more information and letting the elder remain independent. Half of the family caregivers mentioned this benefit unprompted and thought it avoided having them treat the elders “like a child”. One caregiver explained that TLC, “Still gives the power and a lot of independence [to the elder] and you still know they’re doing what needs to be done”.

### *Peace of Mind*

In general, the system reduced the elders’ anxiety and made them feel safer living alone. Eight of 12 elders responded with a 9 or 10 on a scale of 1 to 10 where 10 equaled feeling “much more safe living/staying alone” (Table 2). All 6 of the elders with family caregivers thought the technology increased their safety at home. As one elder explained, “It’s much more safe living alone, having that. Someone else is on it, watching my actions. If all of a sudden it came to a stop, they’d want to know why”. The monitor also “relieves a lot of stress” for these elders and helped them worry less about living alone. An elder explained, “I felt more comfortable. I didn’t feel alone. I knew she was checking on me. It was a very comforting feeling”.

### **Caregiver peace of mind and family caregiver burden**

Using TLC for three months also affected family caregivers’ peace of mind and caregiver burden. As paid caregivers did not use the technology as a passive alert system or a means for improved verbal communication, the effect of the system on their peace of mind was not as great.

### *Peace of mind for family caregivers*

At least 5 of the 6 family caregivers felt safer with the elder living alone. A typical comment included, “I can come home from work and see she’s up and about. Or as she

says, ‘I’m still breathing’”. A concern noted by one family caregiver was that at times the program gave the elder a “false sense of security and being safe. [The elder would say,] ‘You can see what I’m doing. You know I’m safe.’ But it wasn’t always completely clear”. The system gives an indication of what is going on with the elder, but does not provide definitive information. Nonetheless, the general level of satisfaction of most family caregivers with TLC was summarized by one caregiver who said, “I like it. It was very useful, helpful information. I had the peace of mind [I needed], but wasn’t invading her time and space every day, treating her like a child”.

### *Peace of mind for paid caregivers*

Four of the six paid caregivers and one of the service provider managers felt more confident in the elder’s ability to live alone as a result of the program. Multiple caregivers explained it was “good to know” that the elders had “the capability to do some things for himself”. Often the system provided information that they otherwise would not have had about the elders’ level of activity during the day, regularity of brushing their teeth, or consistency with taking daily vitamins. A service provider manager summarized the peace of mind the technology gave him by saying, “It’s reassuring to see it in operation. I have a real tangible sense that they’re OK”.

Two paid caregivers mentioned feeling wary or “tight” because they perceived that “someone else was watching over us” through the TLC program. As a result, these caregivers “used more caution” while performing their duties at the elders’ home.

### *Caregiver burden for family caregivers*

At the baseline interview, the average total score on the short form of the Zarit Burden Interview (ZBI) for family caregivers was 14.2 out of possible scores of 0 (no caregiver burden) to 48 (the highest possible caregiver burden). At the three month interview, the mean score had dropped to 13.2. Among the 6 family caregivers, 3 had ZBI scores above 17 at baseline,



indicating a high caregiver burden based on an established threshold<sup>14</sup>. All three of these caregivers had lowered their ZBI scores beneath this threshold by the end of the study. The 3 family caregivers with lower baseline ZBI scores showed a slight increase in scores by the 3 month interview, still remaining beneath the established cut-off for 'high burden'.

In open-ended responses, all the family caregivers mentioned that TLC helped them in ways that can be characterized as reducing role strain. Reducing their burden, the system made things 'quicker and easier' for family caregivers. Additionally, one daughter of an elder explained the reduction of her emotional burden as a caregiver: "We've experienced a role switch and power struggle. It [TLC] does help. She feels like I'm not checking up on her as much". No one mentioned the technology as increasing their caregiver burden in any way.

## Satisfaction

At the baseline interview, 9 of 12 elders, 6 of 6 family caregivers, and 4 of 6 paid caregivers thought the system would help them personally. All of the paid and family caregivers thought TLC would be useful for the elders.

After using the technology for three months, 10 out of the 12 elders said they would be "very likely" or "likely" to use the system if it was free to them, and three-fourths said they would be willing to pay at least a little bit each month for the service. The amount they would be willing to pay varied from \$5 to \$80 a month, with a median amount between \$20-30 a month.

By the end of the study, all of the participants stated they would recommend the system to others. Two elders and 3 caregivers said they would "miss it" once the study was over and the display screen was removed. One elder gushed about the program: "I think it's the greatest invention that ever was".

Additional themes were identified that facilitated user satisfaction and proved to act as

barriers. The good usability of the technology and the absence of privacy issues were both facilitating themes while mechanical and software problems served as barriers to satisfaction with the technology.

## Usability

The technology had generally good usability. Ten out of 12 elders, 4 out of 6 paid caregivers, and all of the family caregivers rated learning to use the technology as a 9 or a 10 on a scale of 1 to 10 where 10 equals "very easy" (Table 2). Typical elder descriptions of the information on the display screen were "straight forward" and "self-explanatory". The display screens' visual component also had great appeal for the users. The legs/feet and apple icons were reported as especially easy to follow on the timeline and the rotating background pictures drew elders to the screen throughout the day.

Eleven out of 12 elders rated the bracelet "very easy" to put on and take off. Four elders became so accustomed to wearing it that they sometimes forgot to take it off when running errands outside the home or when going to bed. Eight of the elders rated the bracelet as "very comfortable", with the remaining elders rating the bracelet as "somewhat comfortable". At times the bracelet was reported to be itchy, especially in hot weather, and was described as "bulky" or "big" by two people. One elder summed up her experience with the bracelet: "It's alright with me. At times it bothered me. I had to get used to it. Then I got so dog-gone used to it I started wearing it to bed!" Family caregivers were able to effortlessly 'watch' the elder from afar through the display screen, and 4 caregivers reported that the system was so simple that they "didn't have to do anything" to use it. Two caregivers expressed a common sentiment by saying TLC was "a piece of cake".

All 6 of the paid caregivers liked the extra information the program provided. English was the second language for all of the paid caregivers, and one caregiver expressed her

satisfaction with the simple icons by saying, “my English is poor, but I can understand the pictures”. One explained her satisfaction with the additional information provided, “I appreciate the awareness I have of knowing what she’s doing”. Another noted that with TLC, “I know if he took his medications or ate something or brushed his teeth. I didn’t know that before”. Note that this caregiver used the vitamin monitoring as a proxy for medication monitoring.

## *Privacy*

Ten of 12 elders felt the privacy of the information about them was protected sufficiently by the system. Three elders explained that the type of information conveyed was not especially personal. A typical comment by an elder was, “What information I was sharing with this situation is not really my private life, so there was no problem sharing”. Three others thought having their caregivers know about their daily habits was okay because it was intended to help them. An elder explained, “It’s like going to the doctor’s. If you don’t tell a doctor what’s wrong, it won’t help you. [The TLC technology is] there to help, not hinder”.

All study participants generally agreed that the system provided information in an unobtrusive way. As a service provider manager said, “It’s not too intrusive, like a video camera would be, and [the elder] has agreed. It’s a nice happy medium”.

## *Problems*

Mechanical and software problems were identified with the sensor bracelet, object sensors, and display screen. The most frequent problems identified were displays being out of date by up to two days (because of anomalies in the picture frame service used), activities not being reported (primarily because many sensor batteries expired sooner than expected) and a breakage in the loop antenna of the wrist worn wireless bracelet (because of a structurally weak solder). These anomalies were mostly reported to Intel staff by elders during the study and fixed in short order. Subjects were forgiving of technical

problems during this pilot test, but commonly expressed the importance of having problems fixed if elders and caregivers were relying on the technology in the future. Technical problems and their resolution are discussed in greater detail in an upcoming article.

## **Suggestions for future use.**

At baseline, 5 elders, 4 family caregivers, and 1 paid caregiver mentioned that using TLC as a type of emergency monitoring system for caregivers would be a potential benefit of the technology. This technology was not originally intended to be used in this capacity beyond passively providing activity information; however, participants had many suggestions for how to facilitate more immediate emergency monitoring. These suggestions centered on increasing the detail of the display screen information. One family caregiver suggestion for improving the system’s communication capabilities was to have a “two-way communication” option, such as a button to press to connect the elder’s and caregiver’s display screens like a walkie-talkie. This caregiver also suggested enabling an elder to input details (such as text or alert warnings) that would then appear on the caregiver’s screen. Other caregivers thought warnings could be automated.

Some family caregivers wished there were more details with TLC, but recognized that could bring up additional privacy concerns. One caregiver explained it would be better “if [TLC] was a touch more specific about what [the elder] was doing. [Maybe with] a web cam, although she might have privacy issues with that”.

A third of participants referenced using the vitamin icon as a proxy for prescription medication. Elders and caregivers recommended that medication management be incorporated into the system.

## **DISCUSSION**

The results from this pilot study are positive with subjects using TLC and valuing its benefits despite technical problems.

# Remote monitoring

The system reminded elders to perform necessary daily tasks such as eating, taking vitamins and getting exercise. It is of note that half of the elders discussed this technology benefit without being queried directly about it. The remaining elders said that they did not really need the technology at this point in their lives, but that it would have provided helpful reminders if they had needed it. Because recruitment for this study did not include detailed medical screening, we do not know the actual health status of participants. In a future study it will be important to more carefully screen participants' health status to identify for what populations the system works best. For instance, at least 2 paid caregivers thought that the technology could be useful for elders with cognitive and/or memory problems - a population that was not explicitly included in this study. Other studies of smart home or remote monitoring technology have included elders suffering from dementia, diabetes, and heart disease and found the technology to generally promote independence and enhance the users' ability for self-regulation<sup>16</sup>.

A concern that was voiced in this study is that elders need social interaction and that technology cannot be used to substitute for that interaction. Studies have found that certain types of technology (such as video phones) can enhance social interaction with family members and reduce isolation among elders living in institutionalized care<sup>17</sup>. In some cases our system increased verbal communication between the elder and caregiver, and in other cases it decreased the frequency of 'check-ins' via phone or in-person visits. Elders did not report any troubling decreases in verbal communication or social activity. In cases where communication with the caregiver did decrease in frequency, enjoyable social interaction appeared to simultaneously increase. In a future larger study, we might want to examine the bidirectional effects of this technology on communication and social interaction.

We initially thought that privacy might be a significant barrier to elders using the

technology. As a subject in this study explained, when providing care, "there's a certain amount of privacy that's bargained away...The assumption is too much privacy endangers". Other qualitative research has identified privacy and ethical considerations as important barriers to adopting technology for long-term care at home. In general, elders stress the need to find a balance between ensuring safety and security and abdicating independence and individual rights in long-term care settings<sup>18</sup>. More specifically, in nursing homes the use of video cameras to protect the elders from abuse or neglect has faced numerous privacy concerns<sup>19</sup> and it is standard practice to try and minimize the intrusion into an elder's private life with any telemonitoring system<sup>12</sup>. Nonetheless, privacy did not appear to be a significant barrier in recruiting elders for the study. Only one person cited privacy as a reason not to participate. Perhaps elders did not express concerns about privacy because they knew that they could disconnect themselves from TLC whenever they chose; having "control over a zone of intimacy" has been described as an essential component to maintaining privacy rights<sup>19</sup>. All study subjects felt the elder's privacy was maintained and no one reported disconnecting the system in order to increase privacy.

The role of the family caregiver in supporting elders needing long-term care cannot be overstated. It is estimated that in 2006 the cost of unpaid family care surpassed the total spent on formal home health care or nursing home care in the United States<sup>20</sup>. Our study explored whether the system reduced family caregiver stress, but the small sample size resulted in inconclusive findings. In a future study it may be more appropriate to use a measure of caregiver well-being instead of caregiver burden, as caregiver well-being may be more modifiable, whereas measures of caregiver burden rely heavily on the elder's health status<sup>21</sup> and so may underestimate the effectiveness of an intervention in providing assistance to family caregivers<sup>11</sup>.

# Remote monitoring

The positive impact that TLC had on family caregiver well-being was reflected in family caregivers' qualitative responses mentioning a reduction in their anxiety and stress. Enhanced communication could have been part of that change. All of the family caregivers experiencing high caregiver burden reported the positive effect the system had on their communication patterns with the elders. Family caregivers' increased sense of well-being was also supported by the increased peace of mind about elders living alone that the TLC program provided. Family caregivers felt that if something was wrong with the elder, there would be an indication on the display screen. Using the technology as an alert system in this way helped users feel more confident about the elder's safety. This freed family caregivers' time, increased their peace of mind, and enhanced their perception of the elder's safety – all of which are included as "role strain" in the ZBI measure<sup>15</sup>.

The difference in the responses of the family and paid caregivers is of particular interest. All of the family caregivers had very positive reactions to TLC, however the paid caregivers responses were mixed with half of the paid caregivers expressing concern that the technology should not be used to substitute for the human touch or feeling that they were being 'watched over' as they performed their caregiving work. The technology is designed to monitor elders to ensure they are performing needed activities. It is not designed to monitor caregivers. To some extent it may be beneficial if paid caregivers believe that the system monitors them, influencing them to provide an enhanced level of care to the elders. On the other hand, it would be a negative outcome if qualified individuals chose not to be paid caregivers because they felt their day-to-day actions were inappropriately scrutinized. A previous study of surveillance technology used in long-term care settings contends that paid caregivers' interest in increased privacy while providing care is "trumped by their obligation to permit data collection that will

improve the [quality of care] and [quality of life] of the very residents they care for, and by the need to continuously evaluate and upgrade their caregiving skills". Paid caregivers would also be able to use monitoring data as protection against wrongful allegations of misconduct<sup>19</sup>.

In some instances family caregivers wanted to extend the functions of the technology. For example, many participants in this study used the monitoring of vitamins as a proxy for medication monitoring. In an upcoming study, the technology will be used to monitor medication use. Additionally, technology to indicate if the elder is in or out of the house has already been developed, and the technology for detecting falls is currently being field-tested. A system for providing users with real-time information is also being evaluated that would send emergency alerts or warnings, via text messages or automated phone calls, to caregivers. Much research remains to be done on which non-life-threatening events deserve to be communicated to which caregivers through automatic monitoring.

## Study limitations

This study was small, so the utility of the quantitative assessments is limited. The sample size does not allow for statistical analysis of these findings, supporting the need for future larger studies. Qualitative assessments added rich description to help determine the mechanisms by which subjects were satisfied with and used TLC, however, some salient topics were not directly addressed in our questionnaires and only emerged in a few subjects' open-ended responses.

The elders in this study were primarily low income and their need for long-term care services was broadly defined. It may be beneficial to explore interest in this technology among higher income elders and/or to more narrowly define the long-term care needs of the participants. In addition, although recruitment of elders yielded a high level of participation in this study, this may

be a direct result of the financial inducement for primarily low income elders. One elder-family caregiver pair cited the gift certificates as the primary reason they participated, but it is impossible to know if others who mentioned the financial incentives as a motivator would still have participated if that compensation was absent. Participation may be more difficult to achieve among elders who either have a higher income level and/or who are not offered a financial incentive to participate.

Paid caregivers who participated in this study were all paraprofessionals (for instance, homemaker home health aides) without consistent access to an office space or the Internet for viewing the TLC data outside the elder's home. As a result, the paid caregivers were limited to using this technology as a rough review and verification of what the elder had been doing since the last time they visited. A future study should involve paid professional caregivers, for instance, nurses.

Finally, because this study did not have a control group, it is possible that some of the positive outcomes of the technology were only a placebo effect. For example, it is pos-

sible that the elders and family caregivers felt more secure about the elder living alone because they thought the elder's activities were being monitored and that the actual monitoring did not have any effect on the true safety of the elder at home alone. Additionally, a Hawthorne effect could have been observed where elders and caregivers changed their behavior or perceptions simply because they were in a study and not because of the study's intervention.

## Conclusion

This study evaluated the use of a promising new remote monitoring sensor technology, indicating its potential value for supporting independence for elders needing long-term care. Before this technology is implemented on a wide scale it would be beneficial to conduct a study with a larger sample size to validate the results of this study. It may also be beneficial to include paid professional caregivers and more narrowly target the elders involved to determine for what populations the technology is most beneficial. Additionally, a cost analysis of TLC is needed to identify its affordability and marketability.

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# Remote monitoring

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